PSYCO 354
Memory and the Cognitive Sciences

Classical Approaches To Memory

Connectionist Approaches To Memory

Embodied Approaches To Memory

The Art Of Memory: Hybrid, Applied Cognitive Science

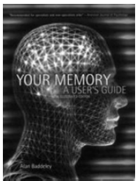
Cognitive Science Of Memory

- One of the prototypical topics in the study of human cognition is memory
- Theories of memory have arisen in classical, connectionist, and embodied cognitive science
- Not surprisingly, each of these theories emphasizes different aspects of human memory
- Nonetheless, hybrid approaches to memory are promising, and are probably most pronounced in the applied art of memory

Classical Study Of Human Memory

- Memory as information processing
- Functional decomposition of memory systems
- What kinds of interacting memory systems are there?
  - Sensory memory
  - Short-term memory
  - Long-term memory
    - Semantic vs episodic
- What structures are used to represent information?
  - Semantic features
  - Frames or Scripts
  - Propositions or Images
- What processes are used to manipulate stored information?

Alan Baddeley

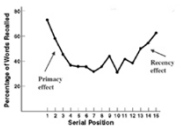


Reverse Engineering Of Memory

- The classical approach is dominated by the functional analysis of memory systems
- Work from the 1950s and 1960s established the modal memory model
- This functional decomposition was supported by behavioral evidence, rejecting implementational studies
  - Span of attention
  - Dissociation of serial position curves
  - "Although the physiological basis of learning and memory is an important and fascinating topic in its own right, my own view is that its current state of development is such that it has as yet very little to contribute to the psychological understanding of memory" (Baddeley, 1982, p.7)

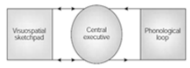
Modal Memory Model

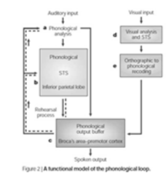
Sperling Memory Span Task



Iterative Analysis Of STM

- Short-term memory was itself reverse engineered into additional functional subsystems
  - Baddeley's working memory model
  - Note the further functional decomposition of 'phonological loop' on the right
- Part of this analysis emphasized, in classical fashion, the nature of the structures and processes involved in short-term memory
  - Conrad's study of STM confusions
  - "The first point to note is that errors are not random. Inspection indicates that when an error of recall is made, the substituted letter is likely to be one which sounds like the correct letter" (Conrad, 1964, p. 77

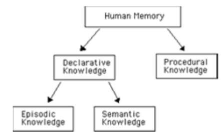


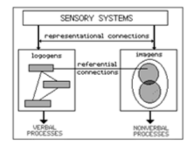


Richard Conrad

Iterative Analysis Of LTM

- LTM itself has undergone extensive, iterative, functional analysis
  - Distinction between episodic and semantic memory
  - Distinction between verbal memory and imagery memory
  - Distinction between declarative and procedural memory
- Again, key issues in this analysis concern the nature of both structures and processes in each memory subsystem
  - How are memories represented?
  - How are memories organized?
  - How are memories stored or retrieved?





Pavio Dual Code Model

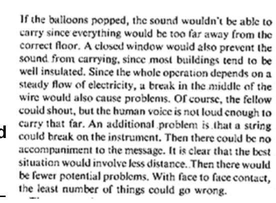
Semantic Memory Is Organized

- In order for the vast amount of material in long term memory to be accessed when needed, it must be organized. Which list is easier to complete?
  - List 1
    - Name a fruit beginning with the letter p:
    - Name an animal beginning with the letter d:
    - Name a metal beginning with the letter i:
    - Name a bird beginning with the letter b:
  - List 2
    - Name a fruit ending with the letter h:
    - Name an animal ending with the letter w:
    - Name a metal ending with the letter r:
    - Name a bird ending with the letter n:
- Organizational principles were central to Bartlett's account of memory
- A classical theory of organization will propose particular structures, and particular methods for operating on them

Sir Frederic Bartlett

Meaningful Organization

- Contexts, and the meanings that they trigger, are critical for understanding
- Consider a classic 1972 study by Bransford and Johnson, who had subjects comprehend and remember passages that were read to them
  - Performance was poor with no context
  - Context was much better with context – particularly if that context was provided before hearing the passage
- Consider the passage on the right, in the absence of context. How hard is it to understand?



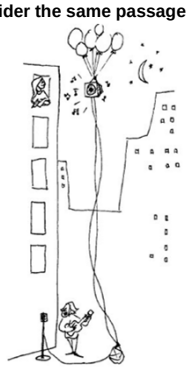
If the balloons popped, the sound wouldn't be able to carry since everything would be too far away from the correct floor. A closed window would also prevent the sound from carrying, since most buildings tend to be well insulated. Since the whole operation depends on a steady flow of electricity, a break in the middle of the wire would also cause problems. Of course, the fellow could shout, but the human voice is not loud enough to carry that far. An additional problem is that a string could break on the instrument. Then there could be no accompaniment to the message. It is clear that the best situation would involve less distance. Then there would be fewer potential problems. With face to face contact, the least number of things could go wrong.

John Bransford

Marcia Johnson

Meaningful Organization Pt. 2

- **Consider the same passage with a picture that provides context**



If the balloons popped, the sound wouldn't be able to carry since everything would be too far away from the correct floor. A closed window would also prevent the sound from carrying, since most buildings tend to be well insulated. Since the whole operation depends on a steady flow of electricity, a break in the middle of the wire would also cause problems. Of course, the fellow could shout, but the human voice is not loud enough to carry that far. An additional problem is that a string could break on the instrument. Then there could be no accompaniment to the message. It is clear that the best situation would involve less distance. Then there would be fewer potential problems. With face to face contact, the least number of things could go wrong.

Hierarchical Organization

- **Evidence suggests a hierarchical organization of semantic memory**
  - **Collins and Quillian (1969) found that it took longer to judge the truth of 'A canary is a bird' than 'A canary is an animal'**
- **Collins and Loftus (1975) proposed hierarchical structure reflects a particular structure, the semantic network**
- **Basic process in this structure is the spreading of activation from nodes through the network**

Alan Collins

Elizabeth Loftus

Features, Spaces, And Exemplars

- **Semantic networks failed to predict some empirical regularities**
  - **Judgements about typical instances faster than atypical (robin-bird vs. penguin-bird)**
- **Some researchers proposed that concepts were stored as sets of features**
- **Other researchers proposed that concepts were stored as points in a multidimensional space**
- **Either proposal could model regularities that suggested that some concepts were exemplars or prototypes of classes**

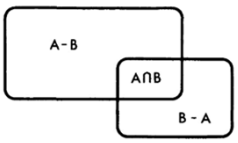


Figure 1. A graphical illustration of the relation between two feature sets.

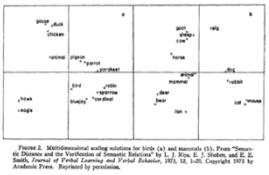


FIGURE 2. Multidimensional scaling solutions for birds (A) and mammals (B). From "Semantic Distance and the Verification of Semantic Relations" by L. J. Rips, E. J. Shoben, and E. E. Smith, *Journal of Verbal Learning and Verbal Behavior*, 1973, 12, 1-20. Copyright 1973 by Academic Press. Reprinted by permission.

The Imagery Debate

- **The imagery debate is an architectural argument between the primitives used to represent visual information in semantic memory**
- **Kosslyn's depictive position**
  - **Mental images are experienced as pictures, and are represented in some format that makes explicit their spatial, depictive, or pictorial properties**
    - **spatial extent**
    - **visual properties**
    - **centrally fine, peripherally fuzzy**
    - **scanned, rotated, translated, etc.**
  - **Spatial properties are part of the architecture**
- **Pylyshyn's propositional position**
  - **Images are experienced as pictures, but are constructed from language-like, propositional primitives**
    - **"The red ball" = RED(ball)**
    - **"The house on the hill" = "ON(house, hill)**
    - **"The tree between the road and the river" = BETWEEN (tree, road, river)**
  - **The spatial properties experienced with mental imagery are not part of the architecture**

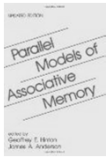
Stephen Kosslyn

Zenon Pylyshyn

Connectionist Study Of Human Memory

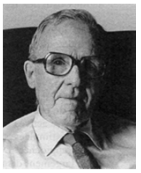
- Focus on associationist principles of memory
- Emphasize biological plausibility, and seem less functional
  - Distributed representations
  - Parallel processing, similarity-based
- Emphasize psychological plausibility
  - Similarity-based errors
  - Graceful degradation
  - Natural creation of prototypes
  - "Storing one memory can affect the other. But herein lies the great strength of the system. Information that is related to, but different from, previously stored information tends to evoke the original pattern of activity – even though the inputs to the system may differ in many details" (Rumelhart & Norman, 1989, p. 18)
- Create models of existing data

Geoff Hinton

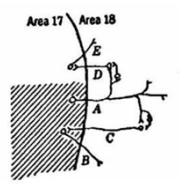


Hebb and Association

- The associationist law of contiguity was the proposal that if two ideas occurred together close in time, then the association between them should be strengthened
- Donald Hebb proposed a neural version of this law to explain the creation of neural networks called cell assemblies
- "When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes place in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased" (Hebb, 1949)

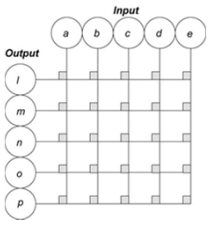


Donald Hebb



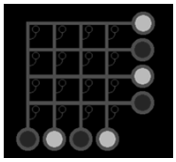
Content Addressable Memory

- Modern views of Hebb learning involve the strengthening of synapses (both excitatory and inhibitory) as well as the weakening of synapses – where synapses are often realized as connections between ANN processors
- These two processes have been combined to create many interesting models of content addressable memories, often called the standard pattern associator
- These memories are the simplest examples of PDP networks, for no hidden units are used, and typically the processing units have a linear activation function

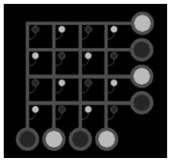


Connectionist Hebb Learning

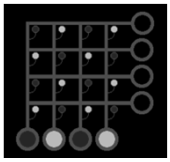
- Present two patterns of activity
- Learn by associating the two patterns
  - Make more excitatory the connections between same-state processors
  - Make more inhibitory the connections between opposite-state processors
- Recall by presenting one of patterns as a cue
  - The network signal should reconstruct the other pattern in the second set of processing units
  - Content-addressable: cue was part of original information learned!



Present Pair



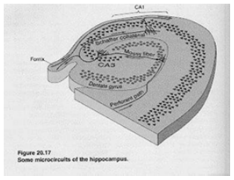
Modify Weights

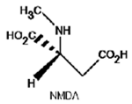


Present Cue to Recall

Biological Plausibility Of Hebb Learning

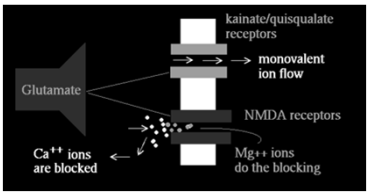
- **The CA1 layer of the hippocampus has many NMDA receptors**
- **Postsynaptic activation of NMDA receptors drives long term changes in synaptic efficacy similar to Hebb's account of learning**
  - **Long-term potentiation (LTP) is a long-term increase in synaptic efficacy that occurs when presynaptic activity is coupled with postsynaptic depolarization**
  - **LTP is NMDA dependent**
- **"By now we know the Hebb rule works by means of a learning window in the context of spike-timing-dependent synaptic plasticity" (van Hemmen & Senn, 2002, p. 317).**

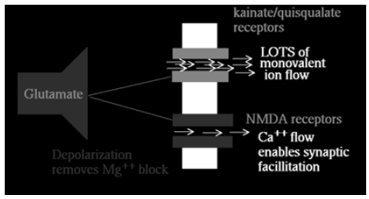




Neural Mechanism Of Hebb Learning

- **With low frequency presynaptic activity, then LTP does not occur because NMDA receptors are blocked**
- **High frequency resynaptic activity coupled with postsynaptic activity (contiguity!) removes the block, allowing NMDA receptors to function, and allowing synaptic efficacy to be modified**





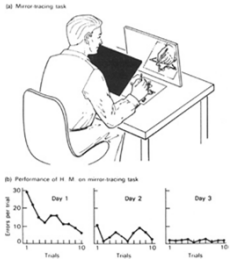
Embodied Study Of Human Memory

- **Memory not as information processing (laying down internal structure) but as embodied interaction with a world**
  - **Emphasis on action**
  - **Possibility of scaffolding**
  - **Cultural, social, environmental factors are key**
  - **Everyday or natural memory**
  - **Reaction against traditional perspective:**
  - **"You need only tell any friend, not himself a psychologist, that you study memory. Given even a little encouragement, your friend will describe all kinds of interesting phenomena: the limitations of his memory for early for early childhood, his inability to remember appointments, etc. Our [classical] research, of course, has virtually nothing to say about any of these topics (Neisser, 1982, p. 5)**

Skills Are Distinct From Facts

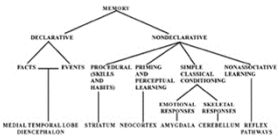
- **After surgery that resulted in the bilateral removal of his hippocampus, Henry Molaison was unable to form new memories, though existing memories were intact**
  - **Dr. MILNER: Do you know what you did yesterday?**
  - **H.M.: No, I don't.**
  - **Dr. MILNER: How about this morning?**
  - **H.M.: I don't even remember that.**
  - **Dr. MILNER: Could you tell me what you had for lunch today?**
  - **H.M.: I don't know, to tell you the truth**
- **But in 1962 Brenda Milner proved that <u>could</u> learn new motor skills, even though he did not remember learning them**
- **Memory for skills or actions are mediated by different systems than those for memory of concepts or episodes**

HM



Memory Systems And The Brain

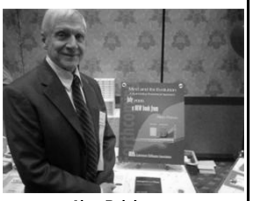
- **Modern studies of the cognitive neuroscience of memory indicate that different kinds of memories (e.g. declarative vs. procedural) are processed by different brain systems**
  - **Cabeza and Nyberg 2000 review of brain imaging studies**
- **Such systems act in parallel to support remembering, as an embodied approach would predict**
  - **"The memory systems of the brain operate in parallel to support behavior" (Squire, 2004, p. 174)**



Larry Squire

Visual Imagery And Memory

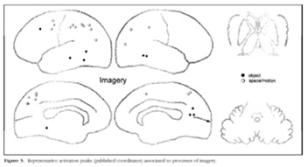
- **For thousands of years, advice to improving memory has made a key point: create mental images to improve memory**
  - **"All you need to do is form a ridiculous picture, or image, in your mind's eye" (Lorayne & Lucas, 1974, p. 9)**
- **Pavio (1971) summarized the results of extensive studies by himself and others, showing that visual imagery has an extraordinarily powerful effect on memory**
- **The more concrete the concept, the more easily it can be imaged, the better can it be retained in memory**
  - **The evidence on the effectiveness of bizarre images is inconclusive!**

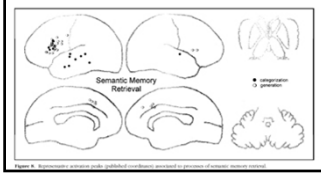


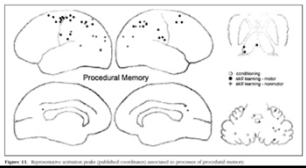
Alan Paivio

Imagery And Action

- **Why does imagery aid memory?**
- **One possibility is that images engage systems involved in action**
  - **We can point to or grasp imagined objects (Pylyshyn, 2004)**
  - **Cabeza and Nyberg's (2000) brain image review suggests imagery and procedural memory share many more neural mechanisms than do imagery and semantic memory**

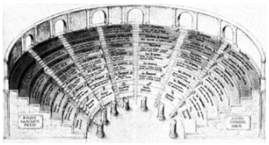




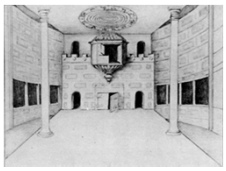


Memory Palaces And Places

- **In the method of loci, memories are associated by being placed in locations in an imagined building**
- **With the renaissance of the art of memory in the 16th century, some proposed constructing real artefacts that could be used as representation of knowledge: scaffolding**
- **Related is the notion of context-dependent memory**
  - **Godden and Baddeley (1975) had divers learn and recall word lists under water and on dry land**
  - **Recall was better when performed in the same environment as learning!**



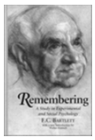
16th century memory theatre of Giulio Camillo



Fludd's 16th century memory theatre: based on the Globe?

The Ecology Of Memory

- **Bartlett is often seen as an early pioneer of cognitivism, laying the groundwork for schema theory in 1932**
- **However, he viewed his research as being about the social and cultural processes involved in memory**
  - **Note the subtitle of his book**
  - **a reaction against Ebbinghaus**
  - **"My aim was to try to find out as much as I could about its character and implications as an active process, and as it takes place in the ordinary course of daily life, as free as possible from any specially imposed conditions other than those of the natural environment"**
- **Neisser continued this tradition of Bartlett's**
  - **"We have almost no systematic knowledge about memory as it occurs in the course of everyday life"**
  - **"The challenge will be to shift from testing hypotheses for their own sake to using them as tools for the exploration of reality"**



Ulric Neisser

Events And Memory

- **People integrate context into their memories**
- **How that context is structured and how it changes can also influence memory effectiveness**
  - **In a virtual environment, subject's pick up an object and carry it to a new location**
  - **Sometimes new location involves going through a doorway, other times not**
  - **Memory probe: give shape and color of object currently held, or of object last put down**
  - **Memory is better for objects that 'move' with subject**
  - **Memory for previous object is worse – the more so if they go through a doorway when changing locations!**
- **When people move through doorways, memory for objects that have been interacted with is reduced!**
- **"The architecture of the environment interacts with the architecture of cognition" (Radvansky et al., 2010)**

Gabriel Radvansky

Activity Theory And Memory

- **Sylvia Scribner championed an activity theory of memory that is explicitly embodied, following the tradition of Vygotsky**
  - **Activity theory does not focus on either memory structures in the head or in the environment but instead focuses on the mutual construction of both**
  - **Activity-based theories of memory are ecological in the sense that they must take particular settings into account**
  - **Memory is a social and cognitive process**
    - **"It can no more be separated into its cognitive and social components than table salt can be separated into sodium and chloride while retaining its saltiness" (Scribner & Beach, 1993, p. 188)**
- **Theory in action: Beachfound that as bartending students became more experienced, they relied less on verbal mnemonic cues (drink names and recipes), and more on material mnemonic cues (glass shape, color & amount of liquid in glass), where the latter are based on social conventions**

King Beach

The Art Of Memory

- **In addition to the modern study of memory mechanisms, humans for thousands of years have developed artificial techniques for improving memory**
- **Such techniques are called mnemonics**
- **Many mnemonic methods appear to exploit aspects of the three different approaches to memory that we have discussed to this point**
- **Mnemonic methods – the artificial memory – paint an optimistic vision of a hybrid, applied cognitive science**

Peg Word Rhyme In Action

- Most artificial memory techniques lean on association as part of their method
- New information must be linked with information that has already been firmly established in memory
- A lot of work is required to store this info for later use
- Example: peg word rhyme method
  - Learn the rhyme
    - One is a bun
    - Two is a shoe
    - Three is a tree
    - Four is a door
    - Five is a hive
    - Six are sticks
    - Seven is heaven
    - Eight is a gate
    - Nine is wine
    - Ten is a hen

  - Learn a serial list by making an image linking TBR item with the object in the rhyme
  - Use the number to recall the object, and the object to recall the image, in order to recall objects in order

Levels of Processing

- Craik and Lockhart (1972) proposed an alternative to the modal memory model: levels of processing
- This model emphasized the process of encoding
- Consider the word 'Table'
  - Some subjects asked: "Is the word in capitals?" (Structural level)
  - Some subjects asked: "Does the word rhyme with able?" (Phonetic level)
  - Some subjects asked: "Does the word fit in the sentence "The man sat on the ...."?" (Semantic level)
- Craik and Lockhart found the deeper the level of processing, the better the recall
  - "We suggest that trace persistence is a function of depth of analysis, with deeper levels of analysis associated with more elaborate, longer lasting, and stronger traces" (Craik & Lockhart, 1972, p. 675)

Fergus Craik

Robert Lockhart

Mnemonics and Levels of Processing

- The major system for remembering strings of digits is similar to levels of processing
- It involves stages of recoding, each moving to a deeper level of elaboration
  - Recode digits as consonant sounds
  - Add vowels to make words, phrases, sentences
  - Make images that capture meaning of the phrases
  - When recalled, decode back into original digit string

Francis Fauvel-Gouraud

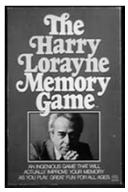
Numeral	Associated Consonants	Mnemonic
0	s, z, soft c	"z" is the first letter of zero. The other letters sound similar
1	d, t	d & t have one downstroke and sound similar
2	n	n has two downstrokes
3	m	M has three downstrokes
4	r	last letter of four
5	l	L is the Roman Numeral for 50, L from hand shape
6	j, sh, soft "ch", dg, zh, soft "g"	a script j has a lower loop / g is almost a 6 flipped over
7	k, hard c, hard g, hard "ch", q, qu	capital K "contains" two sevens
8	f, v	script f resembles a figure-8. V-8 juice
9	b, p	p is a mirror-image 9. b resembles a rotated 9

Major System Examples

- Consider these examples of using the major system
- Notice how they involve association (involving the required translation of digits to consonants), as well as elaborated meaning and the use of strange images
- Dawson office phone number
  - 780 492 5175
  - cvs rpn ldcl cvs rbn ldcl
  - "Caves reopen old coal" or "Caves Robin load coal"
  - Image of Dawson office as caves in a reopened coal mine
  - Image of Dawson office as many bat caves, in one of them Robin is loading coal
- Dawson lab phone number
  - 780 492 7850
  - Cvs rbn cvls cfs rpn kfls
  - "Caves rip nice veils" or "Cough sour pink flies"
  - Image of Dawson lab as many caves; bride walking through lab has nice veils ripped by the walls or of dawson in lab coughing up sour pink flies

Elaborated Peg word

- **Mnemonist Harry Lorayne has popularized a set of peg words that can be used to remember a serial list of 100 items**
  - **Learn the words in the table below**
  - **Note how they can be converted into numbers by the major method**
- **They can then be used as anchors in creating images of to-be-remembered material**
- **This combines association and imagery**



Harry Lorayne

	0	1	2	3	4	5	6	7	8	9
0		tie	Noah	Ma	rye	law	shoe	Cow	ivy	bee
1	toes	tot	tin	tomb	tire	towel	dish	tack	dove	tub
2	nose	net	nun	name	Nero	nail	notch	neck	knife	knob
3	mouse	mat	moon	mummy	mower	mule	match	mug	movie	mop
4	rose	rod	rain	ram	rower	roll	roach	rock	roof	rope
5	lace	lot	lion	loom	lure	lily	leech	log	lava	lip
6	cheese	sheet	chain	chum	cherry	jail	choo choo	chalk	chef	ship
7	case	cot	coin	comb	car	coal	cage	coke	cave	cob
8	fuzz	fit	phone	foam	fur	file	fish	fog	fife	fob
9	bus	bat	bone	bum	bear	bell	beach	book	puff	pipe
10	disease									

Method Of Loci

- **One of the oldest memory techniques is the method of loci**
  - **One takes a journey through a familiar place, such as a building with different rooms**
  - **At each location in the building, an image is created of something to be remembered, and that image is placed in the location**
  - **To recall, go through the journey again, looking at the images placed in each location to recall**
- **Note how this method is associative (using well-learned information as an anchor), representational (visual imagery) and embodied (moving through a familiar setting)**
- **Note too how this method is analogous to Lorayne's peg word approach**

Andi Bell explains the method of loci

Chunking

- **In 1956, George Miller helped launch the cognitive revolution when he published his famous "magical number seven" article in *Psychological Review***
- **Miller argued that the absolute span of short term memory limited it to holding only about 7 items**
- **However, this did not limit what could be remembered, because information could be reorganized into chunks**
- **"Since the memory span is a fixed number of chunks, we can increase the number of bits of information that it contains by simply building larger and larger chunks, each chunk containing more information than before" (Miller, 1956**

George Miller

Mnemonic Chunking

- **Clearly most of the mnemonic techniques are variations on chunking, to compact a great deal of information into a small, meaningful, easier to remember container**
- **Use the method of loci to remember the following words in pairs, i.e. 14 words remembered as 7 chunks:**
- motor- towel; bone-jail; mule-fob; moon-movie; roach-notch; ram-movie; moon-cob

Place 1 (front walkway)	Car motor lying on top of a towel
Place 2 (front lobby)	Bones making up jail cell
Place 3 (walk-in closet)	Mule wearing watch chain eating corn
Place 4 bathroom)	Moon as a giant projector for a movie on a screen
Place 5 (kitchen)	Giant cockroach with a notch cut out of it
Place 6 (back pantry)	Ram standing at a drive-in watching a movie
Place 7 (dining room)	Moon inside leaves of a corn cob

Mnemonic Chunking

- **Clearly most of the mnemonic techniques are variations on chunking, to compact a great deal of information into a small, meaningful, easier to remember container**
- **Use the method of loci to remember the following words in pairs, i.e. 14 words remembered as 7 chunks:**
- motor- towel; bone-jail; mule-fob-cob; moon-movie; roach-notch; ram-movie; moon-cob
- **Recall the 14 words in order:**
- Motor towel bone jail mule fob cob moon movie roach notch ram movie moon cob
- **As you recall each word, use the major method to convert the words into consonants, and the consonants into numbers**
- Mtrtlbnjlmlfbmnmvrchrmmvmn
- 3.14 15 92 65 35 89 79 32 38 46 26 43 38 32 79
- **What did you remember? PI – to 30 decimal places**

Moonwalking With Einstein

- **If you are interested in exploring mnemonics further, a popular recent book is Joshua Foer's "Moonwalking With Einstein"**
- **He describes the various techniques that he learned in a year to become the USA memory champion**
- **Most of these techniques borrow from each of the cognitive, connectionist, and embodied perspectives, making the art of memory a ripe domain for a unified and applied cognitive science**