Lecture 26. Memory and Consciousness

Reading Assignment:

TMB2 Section 8.3
Supplementary reading: Article on Consciousness in HBTNN
Our knowledge as individuals is embedded in a network of schemas

"External" schemas: observable patterns of behavior in individuals...and in society
"Internal" schemas: processes within the individual's head
An individual's schemas:

Not determinants of stereotyped behavior

Responsive to an appreciation of current circumstances to guide behavior in more or less flexible ways

A situation is represented (whether this is conscious or unconscious, repressed or not) by activating a network of schemas which embody what — for the organism or machine, in the context — are the significant aspects of the situation.

These then determine a course of action by a process of analogy formation, planning, and schema interaction which need have little in common with formal deduction.
**Short-Term Memory (STM) vs. Long-Term Memory (LTM)**

**STM:** A *working memory* of *current* relevance to the subject.
- an assemblage of schema instances
- an adaptable structure linked to a whole network of knowledge

**LTM:** A network of schemas constituting the knowledge (both explicit and implicit) of the organism
- Skills and habits
- Memories for specific episodes

**Amnesia**
Retrograde amnesia the loss of some memories formed *before* the damage
Anterograde amnesia: a difficulty in forming new memories *thereafter.*
Consolidation

Memories are not "fixed" immediately but rather stabilize over a long period of time. In a test of its effects of on the ability to remember television programs, Electro-Convulsive Therapy (ECT) was found, one hour after the fifth treatment, to selectively impair memory for programs broadcast one to two years previously although memory for older programs was normal (Squire, Slater and Chace 1975).

Thus there is both gradual forgetting and a parallel increase in resistance to disruption of the memories that remain - over a surprisingly long time base.
Scoville and Milner, 1957
Cutting both sides of the medial temporal lobes yielded an inability to form new episodic memories.
However, Milner 1962 observed that HM could learn new motor skills!
Cohen and Squire 1980: amnesiacs match normals in their acquisition and retention curves for the skill of mirror-reading complex words, but did not recall having learned it.

A priming task:

- A subject is shown a list of words such that each has the property that its first 3 letters can occur as the prefix of many different words.
- If, within 2 hours, the subject is shown such a prefix and asked to give a word that completes it, he will offer the exhibited word with 50% chance, even though there would only be a 10% chance of choosing the word without priming.

Both amnesiacs and normals exhibit this skill, but if asked why the word was chosen:
- The normal will say "Because you showed it to me"
- The amnesic will say "Oh, it just popped into my head."
Squire 1986 argues that amnesiacs can learn a larger domain of **procedural** skills or habits — but with no conscious knowledge of having done so.

What amnesia affects is, according to Squire, declarative learning - including episodic learning - and this needs hippocampus and mammillary bodies, whereas "skill memory" does not.

Without further hierarchical refinement, synaptic models of memory (cf. Sections 3.3 and 8.2) seem to capture only "procedural" memory.
Rozin (1976) on Phylogeny

- Procedural learning may be phylogenetically old, having developed as a collection of encapsulated special-purpose abilities of specific neural systems to register cumulative changes in their functioning.

- By contrast, the capacity for declarative learning reaches its full development only with the elaboration of medial temporal areas in mammals, especially the hippocampus and related cortical areas.
Tasks learnable by animals which may capture the procedural/declarative distinction

One ability which seems to involve declarative or event-specific memory, and which is abolished by hippocampal lesions of the monkey, is the delayed non-matching to sample.

- The monkey is rewarded for picking up an object;
- Later, it is presented with two objects and must choose the one that is different to get a second reward.

The amygdaloid complex is linked directly and reciprocally to both sensory-specific and multimodal cortical association areas. The amygdala projects directly to association cortex. The hippocampal formation also has afferent and efferent pathways linking it with cortical areas. The entorhinal cortex acts as a funnel whereby the hippocampus communicates widely with cortical association areas.
Hippocampus as "enabler" for cortical storage sites

Amnesiacs with damage to the medial temporal region [recall HM] can answer questions about their remote life, so hippocampus seems to be the site neither of storage nor of retrieval. Mishkin 1982 proposes that the inferotemporal cortex (IT) is not only a site of higher-order visual processes but also the site of visual memories resulting from these processes. Not only are certain perceptual schemas instantiated in IT but the schemas themselves are stored there.

- The ability to form and consolidate new "event schemas" requires the interaction of the "storage areas" with the medial temporal region.
- Yet, eventually, at least some memories can be accessed without the presence of this region.

Rolls 1987 models hippocampus as a cascade of associative networks which evaluate the importance of inputs funneling in from cerebral cortex, and then uses back-projections (not back-propagation!) to signal to cortical areas when the patterns they have just been processing are important enough for storage.
The Brain's Multiple Styles of Learning: Hippocampus

**HM Data:**
Hippocampus encodes
*Episodes: units linked in space and time.*
But the LTM resides in cerebral cortex.

**Rats:**
"Place cells" form cognitive map. Activation of these cells can depend on "input update" or "dynamic remapping."

**Places: units linked in space.**

**Hypothesis:** Hippocampus acts as a temporary memory buffer creating relational indexing schemes:
it packages units and identifies crucial links;
the resultant "relational structures" are then shipped to cortex for long-term storage.
Cerebellum is a sidepath to MPGs:

Hypothesis: Cerebellum is responsible for adjusting metrics within a movement, and for grading the coordination between components of a movement (e.g., reach and grasp).

This modulation and coordination of MPGs is also critical for motor skill learning.

Plasticity within this system provides subtle parameter adjustment dependent on an immense wealth of context.

- For "simple" tunings/coordinations it may be able to "install" the new parameters in other brain regions
- In “complex” cases the tuning depends on the uniquely rich combinatorics of mossy fibers and granule cells, and so cannot be replaced by processing in other regions.
The Brain's Multiple Styles of Learning: Basal Ganglia

[Recall our brief description of BG in presenting the FARS model.]

Basal Ganglia organizes Coordinated Control Programs which are critical for motor skills and higher cognitive function.

Hypothesis:
Prefrontal cortex retrieves the "graph of actions" and primes all "imminent" component motor schemas for immediate execution "at the right moment".

Basal Ganglia determine that moment
• inhibiting each motor schema until it is time to execute it;
• "erasing" the activation of a motor schema once it has completed its role in the ongoing action.
Blindsight (Section 7.4)

The role of tectum in directing whole body movements in frog is analogous to the role of superior colliculus in directing eye movements in cat & monkey (Secs 4.1 & 6.2). Neurologists long held that a monkey (or human) without a visual cortex was blind. But:

Humphrey 1970: "What the Frog's Eye tells the Monkey's Brain": a monkey without visual cortex could use visual cues to grab at moving objects, and use changes in luminance for navigation.

Blindsight: humans without visual cortex can also "see" in this action-oriented sense — but are not conscious of this.

Summary: Humans and monkeys without visual cortex are able to catch moving objects, and navigate towards a bright door, for example, but humans without visual cortex are not conscious that they can see in this sense.
Cajal on Consciousness

Chapter 36, "Structure-Function Relationships In The Cortex" of Cajal's *Histologie du systeme nerveux* (1911):

[I hypothesize] that the entire cerebral cortex is formed by various types of perception and memory areas. …

[I] suggest that attempts to localize intellectual activity, volition, and self-consciousness amount to pursuing a chimera. In our view, cognitive or intellectual operations are not elaborated by a privileged area, but result from the combined activity in a great many first and second-order mnemonic areas. …

[I]n humans and other animals many reflex actions take place that are appropriate for a given situation, and yet are not accompanied by … conscious epiphenomena …. Thus, we do not propose to equate reflex activity and instinct with intellectual activity. …
Cajal offers no particular guidance as to the nature of consciousness. Rather, he advances an associationist ("Pre-Hebbian") theory of memory and perception in which ideas are encoded by groups of neurons, and thought is based on association of ideas as encoded by strengthened synapses between corresponding groups of neurons. We agree with Cajal that many functions of the organism involve the *cooperative computation* of many regions of the brain, but have a far larger database of results from neurophysiology and human brain imaging to guide our hypotheses.
Claims About Consciousness

Consciousness is not a unitary property that can reflect on any and all data represented in the brain. It is quite possible for neural activity to effectively link perception and action without any possible intervention of consciousness.

Data Point: Blindsight

Consciousness is not a direct property of having neurons of a particular structure or complexity because the same data can be represented in two networks of comparable neural complexity, yet be accessible to consciousness only when one of the networks rather than the other is intact.

Data Point: AT and DF
AT and DF: "How" versus "What"

“What” versus “How”:
AT: Goodale and Milner: object parameters for grasp (How) but not for saying or pantomiming
DF: Jeannerod et al.: saying and pantomiming (What) but no “How” except for familiar objects with specific sizes.

Lesson: Even schemas that seem to be normally under conscious control can in fact proceed without our being conscious of their activity.
Arbib and Hesse (1986): *The Construction of Reality*
Arbib (1985): *In Search of the Person*

Our theory (Arbib 1985, Arbib and Hesse 1986), is rooted in the evolutionary ideas of Hughlings Jackson (British 19th century neurologist) who viewed the brain in terms of levels of increasing evolutionary complexity.

An evolutionarily more primitive system allows the evolution of higher-level systems but then return pathways evolve which enable the lower-level system to evolve into a more effective form.

He argued that damage to a "higher" level of the brain caused disinhibited "older" brain regions from controls evolved later, to reveal evolutionarily more primitive behaviors.
Evolution is Subtle

Evolution can operate at many levels. When we see the incredible variety of neural forms and connections, we can no longer view natural selection as a straightforward key to form and function.

Natural selection can operate on the macromolecular building blocks of cells, on crucial cellular subsystems, and on the morphology of cells themselves, as well as the connectivity of these cells and their formation into diverse nuclei. What is selected about a subsystem, then, may be the impact of some change on a larger system or a smaller detail, rather than the immediate change in the subsystem itself.

The genetic code may not specify adult forms so much as the processes of self-organization in cell-assemblies which can yield "normal" connectivity in the adult raised in a normal environment.

The environment which fosters adaptive self-organization may be as much social as physical in nature.
Hughlings Jackson (British 19th century neurologist) viewed the brain in terms of levels of increasing evolutionary complexity: damage to a "higher" level of the brain disinhibited "older" brain regions from controls evolved later, to reveal evolutionarily more primitive behaviors.

Evolution not only yields new schemas connected to the old, but yields reciprocal connections which modify those older schemas. After the addition of a new "hierarchical level", return pathways may provide a new context for the origin of "earlier" levels; evolutionary regression may then be exhibited under certain lesions which damage these "return pathways".
Primate communication subserves coordination of the members of a social group. There is a real continuity from controlling one's own body, to using tools, to "using" another member of one's group to complete some action.

As in blindsight, processes which coordinate a group member need not involve consciousness.

For communication to succeed, the brain of each group member must be able not only to generate communicative signals, but also to integrate signals from other group members into its own ongoing motor planning.

The body schema can be tailored in task-dependent ways that can come to include artifacts and other people as well as one's own body.

As communication evolves (by mechanisms we do not yet understand), the "instructions" that can be given to other members of the group increase in subtlety.
Recall the "evolutionary model" of optic flow (Section 7.2)

Our "evolution" of optic flow offered a Jacksonian analysis:

Evolution not only yields new schemas connected to the old, but yields reciprocal connections which modify those older schemas:
- hierarchical level (basic optic flow $\rightarrow$ edge detection)
- return pathways (edge detection $\rightarrow$ refined optic flow as distinct regions are decoupled)
- evolutionary degradation under certain lesions exemplified in a computationally explicit model
Arbib and Hesse stress the consequences of having a "précis" - a gesturable representation - of intended future movements as it enriches the "information environment" for the rest of the brain. The communication plexus comprises the circuits involved in generating this representation.

The Jacksonian element of our analysis: The evolution of a new system provides an environment for the further evolution of older systems.

The brain of each group member must be able not only to generate such signals, but also to integrate signals from other members of the group into its own ongoing motor planning.

A new process of evolution begins whereby the précis comes to serve not only as a basis for communication between the members of a group, but also as a resource for planning and coordination within the brain itself.
Phenomenology of Consciousness: Director vs. Monitor

“The précis comes to serve ... also as a resource for planning and coordination within the brain itself.”

This "communication plexus" thus evolves a crucial role in schema coordination.

Our thesis is that it is the activity of this co-evolved process that imparts a specifically human dimension to consciousness.

Controller or Observer?
Since lower-level schema activity can often proceed successfully without this highest-level coordination,

- consciousness may sometimes be active, if active at all, as a monitor rather than as a director of action.
- In other cases, the formation of the précis of schema activity plays the crucial role in determining the future course of schema activity, and thus of action.
**Hypothesis:**

- Learning processes involving the intervention of this "communication plexus" constitute the mechanisms of declarative memory. This can include the conscious exercise of skill, as well as episodic memory.
- Those that do not constitute procedural memory.
From Action to Gesture

Hypothesis: The key transition in going from the limited set of vocalizations used in communication by, say, vervet monkeys to the richness of human language came with a migration in time from:

i) An execution/observation matching system [Recall our discussion of mirror neurons (FARS 2)] enabling an individual to recognize the action (as distinct from the mere movement) that another individual is making, to

ii) The individual becoming able to pantomime “this is the action I am about to take”.

In the earliest stages, this may have involved the accidental release of a motor plan from inhibition, thus allowing a brief prefix of the movement to be exhibited before the full action was released - but this "warning gesture" may have served to alert others in time to bias their action in such a way as to yield benefits of adaptive value for groups that could both offer "signals of intention" and make use of them.

Communication evolved to allow one to modify one's intended behavior as one observes the ongoing gestures which signal the intended actions of another tribe member.
Recall the lecture FARS 2:
a theory of the **evolution of human language**
 extending that in:

a theory within the tradition that roots speech in a prior system for communication based on manual gesture.

but enriched by the discovery of a “**mirror system**” in area F5 (part of premotor cortex) in the monkey, which is active both for self-execution of movement and for observation of similar movements by others.

Since monkey F5 is homologous to human Broca’s area, this suggests an evolutionary basis for **language parity** - in which an utterance means roughly the same for speaker and hearer.
Hypothesis 1: The human-monkey common ancestor had:

- **Primate Call System**
  a limited set of species-specific calls

- **Oro-Facial Gesture System**
  a limited set of gestures expressive of emotion and related social indicators

Combinatorial properties for the openness of communication are virtually absent in basic primate calls and oro-facial communication though individual calls may be graded.

**Hypothesis 2**: The capacity for analysis of actions by mirror cells **within the open-ended set of manual behaviors** is at the basis of the evolutionary prevalence of the lateral motor system over the medial system mediating the primate call system in becoming the main communication channel in humans.

Communication is inherently multi-modal.
Hypothesis: A *distinct* manuo-brachial communication system evolved to complement the primate calls/oro-facial communication system.

Our hypothetical sequence for this is:

i. Pragmatic action directed towards a goal object
ii. Pantomime: similar actions are produced away from the goal object
iii. Abstract gestures divorced from their pragmatic origins and available as elements for the formation of compounds which can be paired with meanings in more or less arbitrary fashion.

Combinatorial properties are inherent in the manuo-brachial system. This provided the evolutionary opportunity for Step iv:

iv. The manual-orofacial symbolic system then “recruited” vocalization. Association of vocalization with manual gestures allowed them to assume a more open referential character.
Rudiments of Language pre-Homo sapiens
→ Homo sapiens Language-Ready “from the start”
→ Cultural evolution of Language in “later” Homo Sapiens

The ability for visual scene perception—of *Action-Object Frames*
 in which an actor, an action, and related role players can be
perceived in relationship—was well established in the primate line

**Hypothesis:** The ability to communicate a fair number of such frames was established
in the hominid line **prior to the emergence of Homo sapiens.**

Crucial Caveat: This ability does not requires separate naming of actions and objects!

**The transition to Homo sapiens** may have involved “language amplification” through
increased speech capability, yielding:

An increased ability to name actions and objects *separately* to create an **unlimited**
set of verb-argument structures, and

The ability to compound those structures in diverse ways.

We suggest that many ways of expressing these relationships were the **discovery** of
*Homo sapiens* of many grammatical structures like adjectives, conjunctions such as
*but, and, or or and that, unless, or because*
I.e., these might well have been “post-biological” in their origin.

Issue: How did the needs of human biology and the constraints of the human brain shape
these basic “discoveries”?
Concluding Claims About Consciousness

☆ Human consciousness as we normally experience it is a property of the brain, rather than some separate "mind stuff";
① It is possible that portions of our brain can support forms of "animal awareness" that may enrich human consciousness but seem qualitatively different in nature; but
② What makes human consciousness so different is that it includes an expression of the function of the brain which expresses language.
③ The *communication plexus* underlying language has (by a process of “Jacksonian evolution”) restructured the brain in such a way that consciousness may seem sometimes to be observer and sometimes controller, but
⑤ Consciousness is a distributed property that has little access to many brain regions, and provides a (only partially) verbalizable précis based on the state of other brain regions.