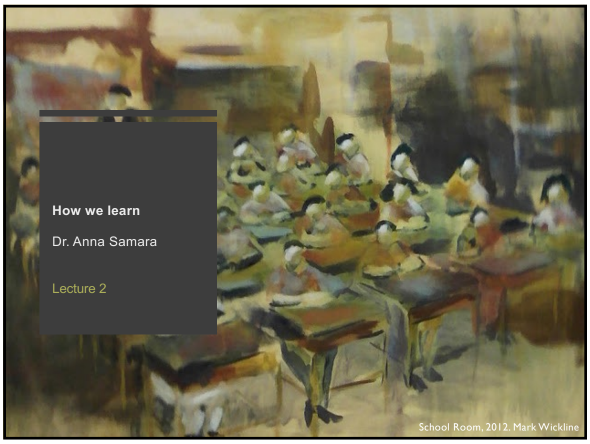

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Roadmap of today's lecture

- Part 1
  - What is learning and why we are good at it
  - Overview of the Multiple Memory Systems (MMS) theory
    - Declarative vs. nondeclarative learning
  - Neurobiological model of language learning
- Part 2
  - Atypical learning: The Procedural Deficit (PD) hypothesis
  - Sleep-dependent learning and memory consolidation
    - Sleep stages and associated biology
    - Evidence on the memory/sleep link

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Learning outcomes

- Provide a working definition of 'learning' and outline why humans are good at it ("four pillars of learning")
- Describe the Rescorla–Wagner model of Pavlovian conditioning and outline its main assumptions
- Contrast the functions of declarative (explicit) and nondeclarative (implicit) long-term memory systems and subsystems that comprise them

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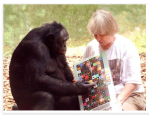
Dehaene (2020). *How we learn*

Why we learn

- Knowledge is essential for survival
- Most of what we know about the world is learnt from our environment rather than being pre-wired in our brain
  - Impossible
    - Human behaviour is too complex!
  - Undesirable
    - Even among the simplest creatures, adapting to unpredictable aspects of the environment through learning brings better chances of survival



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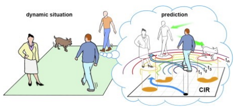
Dehaene (2020). *How we learn*

What is learning?



- To learn is to form an **internal representation** of the external world
  - Surrounding environment
  - Objects and how we interact with them
  - People, their characteristics and our relation to them
  - Our body (e.g., position of our limbs)
  - The language we speak
- We use these mental representations to adapt to changes and make predictions

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How do we learn?

- If synaptic plasticity is omnipresent in the animal world, why are humans so much better at this?
- Four pillars of learning (Dehaene, 2020)

1. Attention→ amplifies the information we focus on
2. Active engagement→ curiosity/hypothesis testing
3. Error feedback→ compares our predictions against reality and corrects our internal models of the world
4. Consolidation→ renders what we have learnt fully automated

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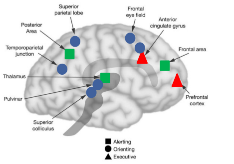
1. Attention

Posner & Rothbart, 2007



- Memory encoding is of limited bandwidth: To navigate complex real-world environments, we must select and attend to goal-relevant information
- Our attentional resources are also limited
- Attentional systems must interact with memory processing to optimize learning

- Attention: Basic set of mechanisms that underlie our awareness of the world and the voluntary regulation of our thoughts and feelings.
  - Alerting: indicates when to attend and adapts our level of vigilance
  - Orienting: signals what to attend to and amplifies objects of interest
  - Executive attention: guides how to process the attended information, selects processes that are relevant to a given task and controls their execution

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2. Active engagement

- Active engagement seems crucial for learning in **everyday situations**
  - learning a driving route as a passenger rather than a driver
  - extracting information from a website when some else controls the scroll bar
- Emphasis on active learning (e.g. flipped classroom)
- Converging research evidence that individual's control over learning evidence is very important
- Active metacognitively guided strategies (e.g., delayed judgments regarding how one remembers items from a list items to be memorized) are useful in allocating additional attention to the material that will benefit most from it (Metacalfe, 2009)

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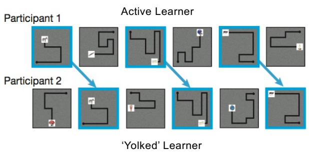
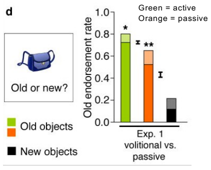
Extra study slide: Voss et al. (2011). Nature Neuroscience

Dynamic visual learning task: 'memorize the objects and their location'
Adults studied arrays of common objects arranged on a grid, viewing one object at a time through a small moving window
Instructions:
- ❑ Condition 1: self-initiated active control of window position (active)
- ❑ Condition 2: movements of active player played back to passive subjects





- ✓ Well-matched experimental design: any observed differences in performance outcome can be only attributed to the effects of active control (relative to passive viewing).
- ✓ Key finding: Subjects showed superior performance for information acquired in the volitional condition both on tests for spatial memory and for item (object) memory (see Figure on the left).

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3. Error feedback

- What types of evidence are available to learners?
1. Positive evidence reinforces successful predictions
   - Hearing the sentence "the boy drunk the milk" constitutes positive evidence that this sentence is possible (grammatical)
2. Negative evidence ('unlearning')
   - Receiving feedback that the sentence is *Milk drunk the boy is impossible (ungrammatical)
   - Unlearning as a result of surprisal associated with prediction error
- Both needed to explain even the most basic aspects of learning in animals (McLaren & Mackintosh 2000, Pearce & Hall 1980, Rescorla & Wagner 1972, Sutton & Barto 199)

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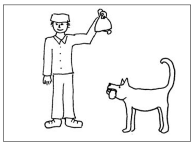
Rescorla & Wagner (1972)

- Pavlov's dogs salivated whenever they heard a bell that they had previously learned to associate with being given food
- 'Naïve' view of Pavlovian conditioning: learning as a simple process of recording cooccurrences is mistaken
- Using a variant of the Pavlov experiment where rates associated tones with an electric shock, Rescorla demonstrated that learning depends not just on how strongly tones and shocks are paired, but also how frequently they are not
  - On each trial, learning depending by how surprised the learner is by the unconditioned stimulus



In **Rescorla-Wagner model of Pavlovian conditioning,** three parameters needed to make quantitative predictions about how much learning will occur:

1. The participant's prior knowledge of an association
2. Salience of Conditioned Stimulus
3. Salience of Unconditioned Stimulus

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To recap

- Good learning involves ….
  - being able to select the appropriate sensory inputs (attention)
  - Being actively engaged with material to be learned (e.g., actively testing hypothesis/making predictions)
  - evaluating the accuracy of its prediction through error feedback (surprisal) processes
- Newly acquired knowledge needs to be consolidated. We will come back to discuss consolidation in Part 2 of today's lecture

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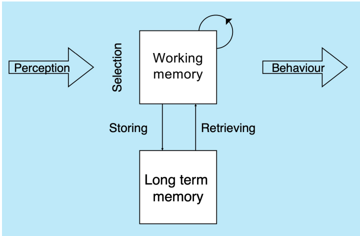
Atkinson–Shiffrin's information processing model of memory



To learn, we need to store information in long-term memory and retrieve it when needed

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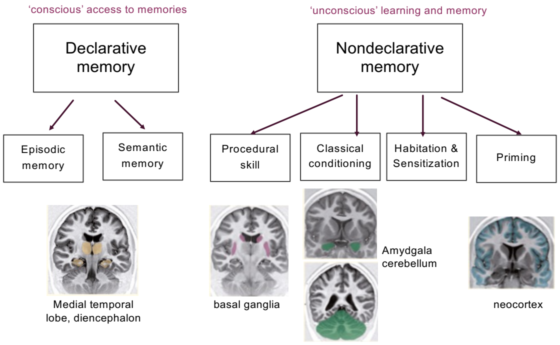
Zola-Morgan & Squire, 1996; Tulving 1985

Multiple memory systems theory



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Declarative memory

- Knowing 'what'
  - Acquisition, storage and use of facts (semantic memories) and events (episodic memories)
  - Found in other vertebrates too (e.g., helps birds remember where they put their acorns)
- Specialized for learning arbitrary bits of information and associating them
- Declarative memories can be consciously recalled ('declared') (though some memories cannot be described verbally)
- Sometimes referred to as explicit memory/learning

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Procedural memory

- Knowing 'how'
- Stores information on how to perform routines and procedures that do not require conscious reflection
  - Motor skills (for example, playing the piano or riding a bicycle)
  - Social skills (e.g., engaging in appropriate social interactions)
- Learning is gradual, eventually knowledge becomes automatized
- May be specialized for learning to predict, especially based on rapid feedback
  - E.g. where to turn left, what is the next
- Sometimes referred to as implicit memory/learning

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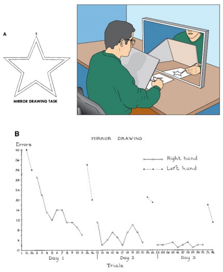
Declarative vs. procedural memory

- 1. Neuropsychological evidence:
  - Amnesic patients have impaired declarative (explicit memory) yet they been shown to have normal performance on several procedural (implicit) memory tasks
  - Patient HM could learn a new procedure (mirror drawing task) but had no recollection of practicing the task
  - Patients with Huntington's disease show the opposite pattern (Heindel et al., 1989)



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Declarative vs. procedural memory

2. Converging evidence from animal work
   - Double dissociations in task acquisition following lesion damage or intra-cerebral drug infusions to the hippocampal system and caudate-putamen
- However: Learning rarely involves isolated systems
  - Multiple memory systems likely to interact with one another: cooperatively (when both systems can contribute solutions, learning cooperatively is advantageous) but also competitively (Sherry & Schacter, 1987)
  - This is particularly true in complex domains of knowledge:
    - Declarative vs. procedural learning system contributions in language learning

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Ullman (2001, 2004; Ullman et al., 1997)

- Declarative-procedural model of typical language
  - Neurobiological model language learning
  - Language engages both declarative and procedural learning and depends on respective pre-existing brain systems
    - Declarative memory/learning: Foundation for the creation of a mental lexicon which stores word-specific knowledge (e.g., words associated with the category 'fruit')
    - Procedural memory/learning: Learning of a mental "grammar" which is concerned with the rule-based procedures that govern the regularities of language

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Bringing it all together

- To learn is to form an internal model of the external world
  - Ubiquitous ability shared with (studied through) animals
  - Dynamic process that adapts to change and error
- Attention, active engagement, error feedback and consolidation (more on this in part 2) help maximize our ability to learn
  - Their functions are not unique to humans but we exploit them much more efficiently than animals

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Bringing it all together

- MSM theory: Prominent model of long-term memory that distinguishes between partially independent and mediated by disparate brain regions memory systems
  - Memory categories offer convenient distinctions but these rarely occur in isolation in real life
  - Distinction between two forms of memory in formulating a declarative-procedural model of typical language (Ullman, 2001, 2004).
    - Model has generated specific hypothesis regarding atypical language development: we come back to discuss in Part 2

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Q & A ON PRE-RECODED LECTURE & SEMINAR

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Thank you for watching!

And see you in Part 2

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