7. Human Memory and Learning

Learning and Prediction

Surprise
It is considered a clue to what people know. We can measure the expectation of a distribution using the **Shannon Entropy**. This is related to the surprise to a sample from the distribution. If the sample differs much from the expectation, then the surprise is higher (the subject is **learning**).

Predictions
Learning produces predictions, and predictions impact processing manipulating the randomness of an environment.

Learning
We need to quantify learning from observable behavior, to separate predictive processes from responses, and to quantify the relation between the two.

Predictions as a window into learning
Notaro et al. (2019)

Explores how humans learn and adapt to changing patterns in their environment by observing their eye movements.

Methodologies

Task Setup: Participants looked at a screen where a target symbol appeared on either the left or right.

- Pret70 Condition: The target had a 70% chance of returning to the same side.
- Pret30 Condition: The target had a 30% chance of returning to the same side.

Eye Tracking: An eye-tracking system captures two main measures

- **Saccade Latency:** The time it takes for the eye to move to the target once it appears. This is used as a measure of surprise.
- **Anticipatory Fixation Offset (AFO):** This measures how much people are predicting the next target's location. A positive AFO means they're looking towards the side of the last target, and a negative AFO means they're looking away.

Mathematical Modeling: Linear regression model to understand how the last few trials influenced both saccade latency and AFO.

Results

Inhibition of Return (IOR): even in the Pret70 condition where returns were expected, saccades to returns were generally slower than saccades to alternations. This suggests a human tendency to explore new locations rather than re-fixate on old ones.

AFO indicated active prediction: The very last trial has a strong, independent impact on predictions, even overriding global probabilities to some extent.

Time Scale of Learning: The impact of past trials on AFO (how far back previous events influenced current predictions) decayed rapidly. This implies that people prioritize recent information, perhaps adapting to non-stationary environments.

Relationship between prediction and behavior
Timme and Lapish (2018)

Problem

Does anticipation (AFO) truly predict how a person will react to a stimulus (measured by Saccade Latency, SL) in a way that aligns with their prior predictions?

Which measure carries more information about the underlying statistical pattern of the environment?

Methodologies
The researchers built upon the experimental setup from Notaro et al. (2019). They analyzed the relationship between AFO and SL.

Correlation Analysis between AFO values and subsequent SLs.

Mutual Information (MI): To determine which measure better reveals the experimental condition. MI quantifies how much knowing one variable tells you about another, without assuming a simple linear relationship.

Results
Human anticipation, measured by AFO, directly influences subsequent reaction times and provides a clearer window into a person's understanding of environmental probabilities than response speed

Human Memory

Ebbinghaus

Memory is a sort of **storage**

The more **repetitions** (practice), the more likely information is to be remembered later.

Memorization is impacted by the **information composition**. There is a difference between massed learning distributed learning (small chunk of information at a time, better performance).

Barlett

Prior knowledge influences memory.

Learning is impacted by culture and society.

Memory is an active process of **construction**: the memorized content is different from the one that was given, as the process of storing (retrieving) in (from) memory is indeed a construction process, that adds and modifies information.

Gestalt psychology

A representation cannot be reduced to the representations of its parts.

Memory is influenced by the configuration of elements and **context**. Material is represented mentally in the same configuration as it exists in the world.

Behaviorism

Memorization is the "**attachment of responses to stimuli**", while forgetting is the "loss of response availability".

Early Neuroscience

Memory is affected more by the amount of **brain tissue** removed, not the location.

Hebb

Cortical organization occurs through "cell assemblies" and "phase sequences".

- A **cell assembly** is a set of associated neurons that work together because they are activated together.
- **Phase sequences** incorporate several cell assemblies. They form systems involving multiple interconnected areas of the brain.

The cognitive revolution in psychology

Within cognitive psychology there are three definitions of memory:

- The **location** where memory is stored.
- The **physical entity** that holds the memory (biological representation in brain activity)
- The **processes** used to acquire (learn), store (encode) or remember (retrieve) information.