Summary 3

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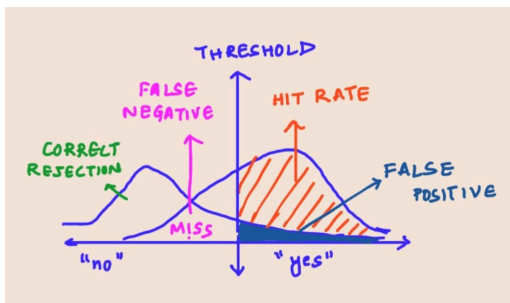
Value-Based Decision Making: Choosing between different options based on subjective value (e.g., reward, utility). The goal is to optimize the decision-making process.

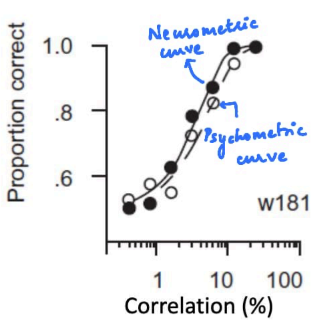
Perceptual-Based Decision Making: Deciding based on sensory information (e.g., color, shape, motion).

Signal Detection Theory (SDT): explains how decisions are made under uncertainty by distinguishing between signal (tumor present) and noise (no tumor). In medical imaging, false positives cause unnecessary procedures, while false negatives delay diagnosis. During the COVID-19 delta wave, many false positives led to excessive CT scans, overwhelming hospitals.



Motion Perception in Monkeys: It is a normative model. This experiment studies motion perception in monkeys by linking MT (middle temporal) neurons to decision-making.

In this experiment, the monkey fixates on a central point while viewing a stimulus where some dots move coherently in one direction while others move randomly. To indicate its perception of motion, the monkey makes a saccadic eye movement toward the target corresponding to the perceived direction.



Correlation(%): is the % of dots moving in same direction

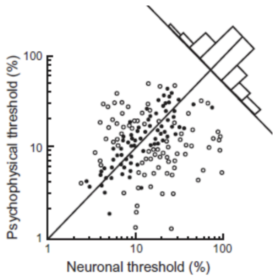
Proportion correct: monkey's accuracy

Psychometric curve: monkey's response

Neurometric curve: MT neuron predictions

Curves closely align: MT neurons reliably predict the monkey's perception

The neuronal threshold measures the sensitivity of a single neuron, while the psychophysical threshold reflects the monkey's overall behavioral sensitivity.



Most data points near the diagonal: A single MT neuron is nearly as good as the monkey at detecting motion

Below diagonal:Neuron is more sensitive, detect motion at low coherence

Above diagonal: Neuron is less sensitive, requiring stronger coherence

Scattered points: Some neurons are better motion detectors than others.

Decision-making relies on small MT neuron population supporting SDT

Conclusion: MT Neuron acts as signal detector

In the MT neuron firing rate vs. time graph, a sharp initial peak indicates rapid motion detection, followed by stabilization. This suggests MT neurons quickly signal motion perception early in processing.

Drift Diffusion Model (DDM)

It describes how decisions emerge by accumulating noisy evidence until a threshold is reached. It is a process model. It is better than Brute force(slower and inefficient).

The decision process acts like a diffusing particle drifting toward a boundary, with the drift rate determining decision speed. Stronger evidence accelerates drift for faster decisions, while weaker signals slow it down, increasing response time. Task difficulty further affects drift—unclear information delays decisions. Bias shifts the starting point closer to a boundary, favoring one choice over the other.

How does DDM work?

Evidence Accumulation: The y-axis represents accumulated evidence, starting from a neutral point, while the x-axis represents time.

Decision Boundaries

- Upper threshold → Enough evidence for a positive decision.
- Lower threshold → Enough evidence for a negative decision.
- If neither is reached, evidence continues accumulating.

Stochastic Evidence Collection: The decision path is squiggly due to neural noise, modeling real-world variability in perception and cognition.

Speed-Accuracy Tradeoff: Lowering decision thresholds leads to faster decisions but increases errors, while raising them results in slower, more accurate choices. In high-stakes situations, higher thresholds are preferred for reliability, whereas in urgent scenarios, lower thresholds enable quicker responses.

Evidence for DDM in MT and LIP

Visual signals first enter the Primary Visual Cortex (V1), where raw motion information is processed. V1 extracts basic visual features but does not accumulate evidence for decision-making.

The Middle Temporal Area (MT/V5) specializes in motion detection. MT neurons respond strongly to motion in their preferred direction and weakly to motion in the opposite direction. MT activity remains stable over time, indicating that this region does not integrate motion evidence.

Decision-making in the Lateral Intraparietal Area (LIP) involves accumulating motion evidence. As evidence builds, LIP neurons increase firing—rightward motion activates rightward-preferring neurons, while leftward-preferring neurons decrease activity. Stronger motion leads to faster accumulation, and once LIP activity reaches a threshold, a saccade is triggered, aligning with the Drift Diffusion Model (DDM).

Neural Representation of Evidence Accumulation

LIP Activity Aligned to Motion Onset :After stimulus onset, LIP neurons briefly dip in firing, (maybe due to attention shifts) before ramping up activity. Firing rate increases proportionally to motion coherence, with stronger signals leading to faster accumulation. This supports the DDM, where LIP integrates noisy sensory input until a decision threshold is reached.

LIP Activity Aligned to Saccade Onset: Once evidence reaches a threshold, monkey commits to a choice, triggering a saccade. Just before movement, LIP activity converges at a common threshold, reflecting decision-making. Stronger motion leads to faster accumulation and shorter reaction times, while weaker signals result in slower decisions.

Manipulating the Decision Process: Artificially stimulating rightward-preferring MT neurons biases perception, making LIP accumulate evidence faster and leading to quicker decisions.Weak electrical currents in MT do not cause direct movement but subtly bias LIP evidence accumulation.

Visualizing the Decision Process: This experiment visualizes decision-making by linking sensory perception to motor responses. A monkey fixates on a central point, views a motion stimulus, and makes a saccade to indicate perceived direction. FEF microstimulation in some trials alters saccade patterns, revealing how sensory input drives motor decisions.The evoked saccade (eye movement) reflects the extent of planning, where the saccade lands indicate how much planning has been done.Longer viewing results in a larger deviation (greater evidence accumulation before commitment).

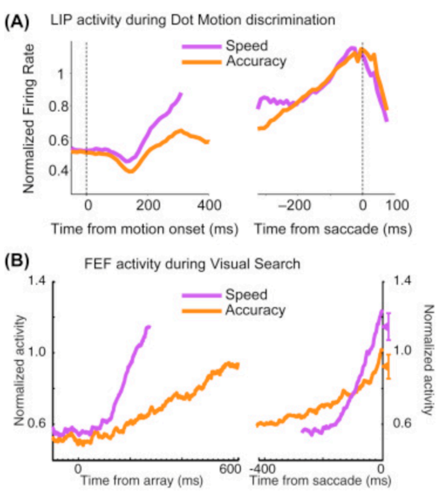
If we plot CPP (Centro-Parietal Positivity, a neural signal linked to evidence accumulation) against time (in milliseconds). The curves represent different coherence levels in a motion discrimination task. Higher coherence levels (stronger stimulus signal) result in stronger CPP, indicating greater evidence accumulation and faster decision-making.

Is decision-making purely sensory, or is it motor-driven?

The decision process is being visualized in EEG data.Motor processes occur in sensory areas, challenging traditional compartmentalization (separating sensory and motor functions).

Brain Imaging: Oxyhemoglobin levels increase due to movement, reflecting brain activity. Deoxyhemoglobin levels serve as a proxy for muscle usage, measurable via transcranial MRI. fMRI shows how perceptual decisions involve face and object recognition in Fusiform Face Area (FFA), specialized for faces and Parahippocampal Place Area (PPA), specialized for places/objects.

Brain as a Prediction Machine: The brain does not passively receive input but instead predicts and updates perceptions.Traditional models focus on feedforward processing (information flows from the senses to higher brain areas).However, real-world perception is feedback dominant, meaning prior knowledge and experience shape what we perceive.



How Do Observers Decide When to Decide?

- In LIP, firing rates start higher under speed pressure but reach the same final level, suggesting a shift in starting point rather than bound height.

This suggests that instead of lowering the decision threshold, the brain shortens the decision process by starting closer to the bound.

- In FEF, firing rates plateau at a higher level for speed, contradicting simple threshold models.

This contradicts the idea that speeding up decisions simply lowers the threshold. Instead, it suggests that the brain imposes a deadline, forcing decisions even with incomplete information.