Intro to EAM

@47th ECVP 2025 Mainz

Margherita Calderan

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Perception into action

Evidence Accumulation Models assume that, upon stimulus presentation, the decision maker:

What is “evidence”?

Neural signals reflecting sensory or internal information relevant to a choice.

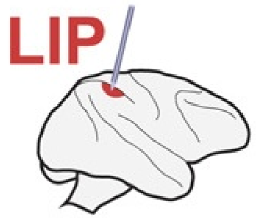
“Are dots moving to the right or to the left?”

- Neurons fire in proportion to motion direction & strength.
- These firing rates = **momentary evidence**.
- Noisy and varies trial-to-trial.

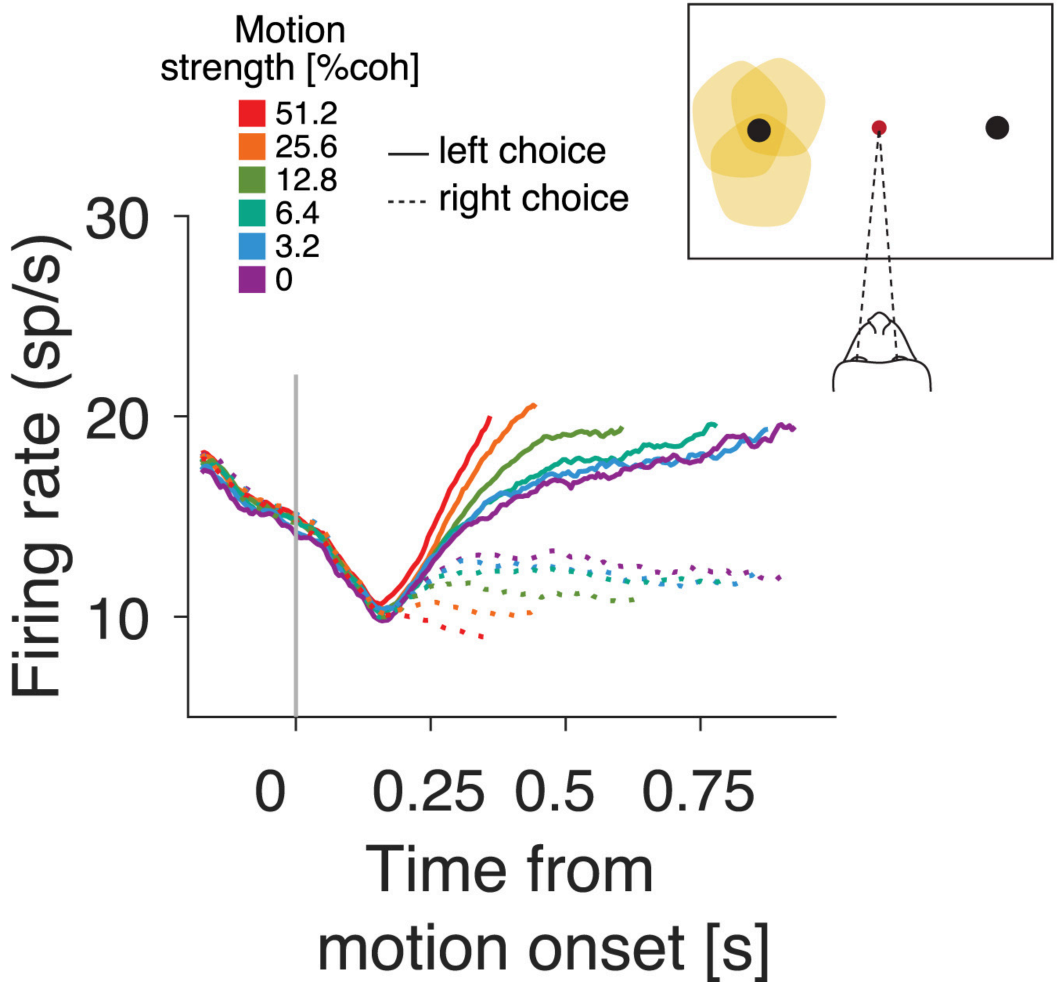
How does the brain accumulate evidence?

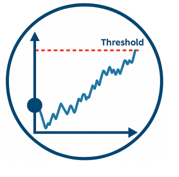
Integrator neurons receive this input

- Neurons in **LIP**, **dlPFC**, or **striatum** ramp up/down over time.
- Reflects **accumulated evidence**

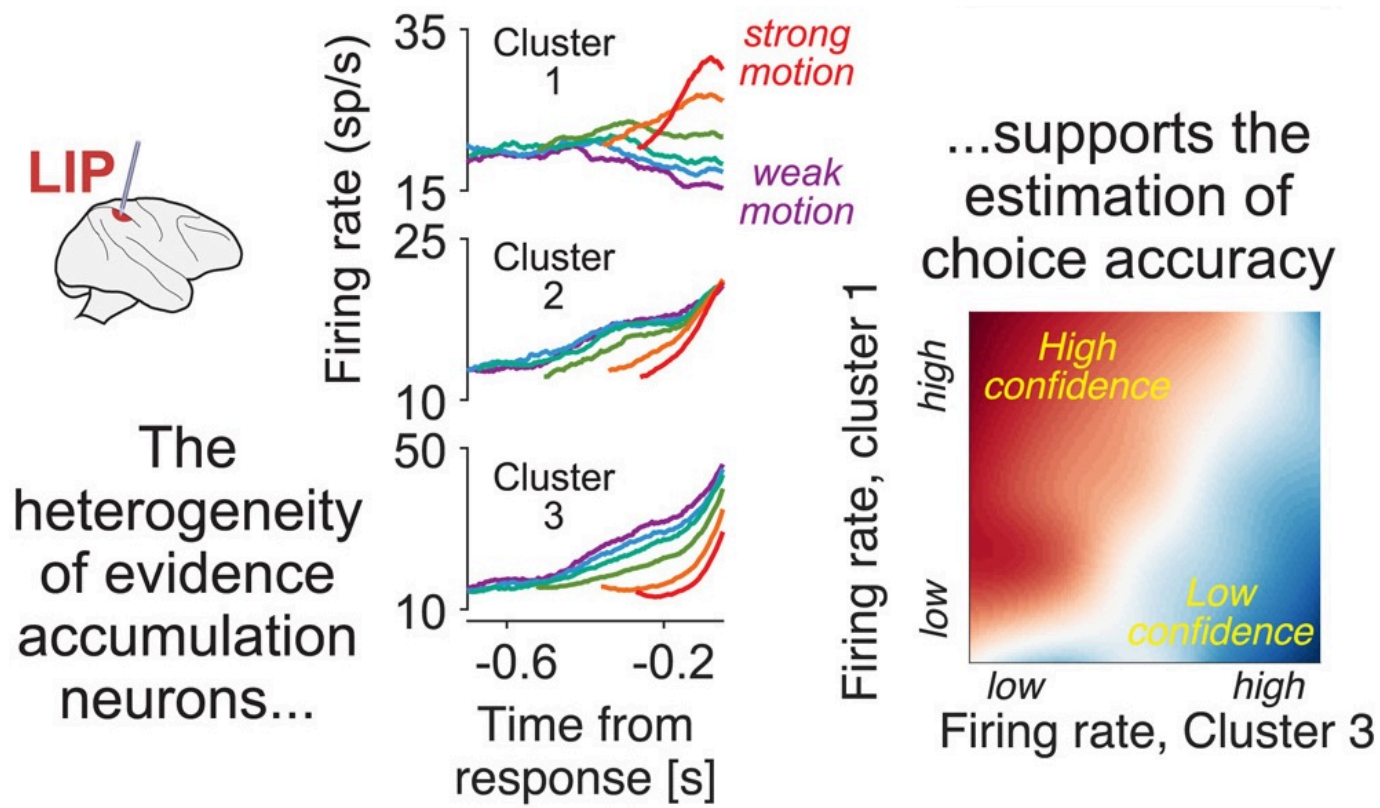


Zylberberg & Shadlen, 2025





Threshold crossing triggers a decision



Zylberberg & Shadlen, 2025

Brain computation of decisions

Cognitive Term	Neural Interpretation
Evidence	Sensory neuron firing rates
Accumulation	Integration in parietal/frontal areas
Noise	Trial-to-trial neural variability
Bound	Decision threshold in firing/activity

Latent Cognitive Parameters

Sequential processing assumption

Total **Response Time (RT)** is modeled as the sum of **three sequential stages**:

1. **Stimulus encoding**
2. **Evidence accumulation** (decision-making)
3. **Motor response execution**

Stages (1) and (3) are captured in the **nondecision time (Ter)** parameter.

EAMs decompose decisions into:

- **Drift rate**
- **Threshold**

Drift Rate

Reflects **evidence strength**

- ⬆ Drift: fast & accurate decisions
- ⬇ Drift: slow, error-prone

> Manipulated by stimulus discriminability/task difficulty

Thresholds

Set before stimulus onset

Reflect **response caution/cognitive control/bias/preference**

- ⬆ Threshold: Slower but more accurate
- ⬇ Threshold: Faster but error-prone

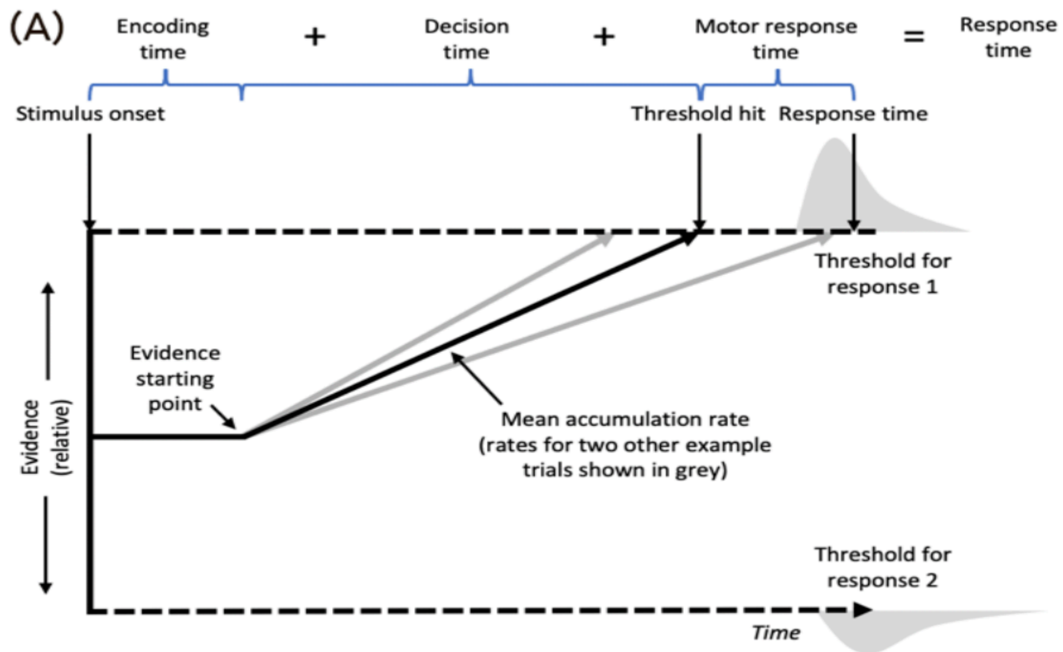
> Manipulate via pre-trial cues or instructions.

Relative Evidence Models

In **relative evidence models** (e.g., Wiener process, Diffusion Decision Model):

- Decision is based on the **difference** in accumulated evidence between two options.

- Suitable for **binary choices**.

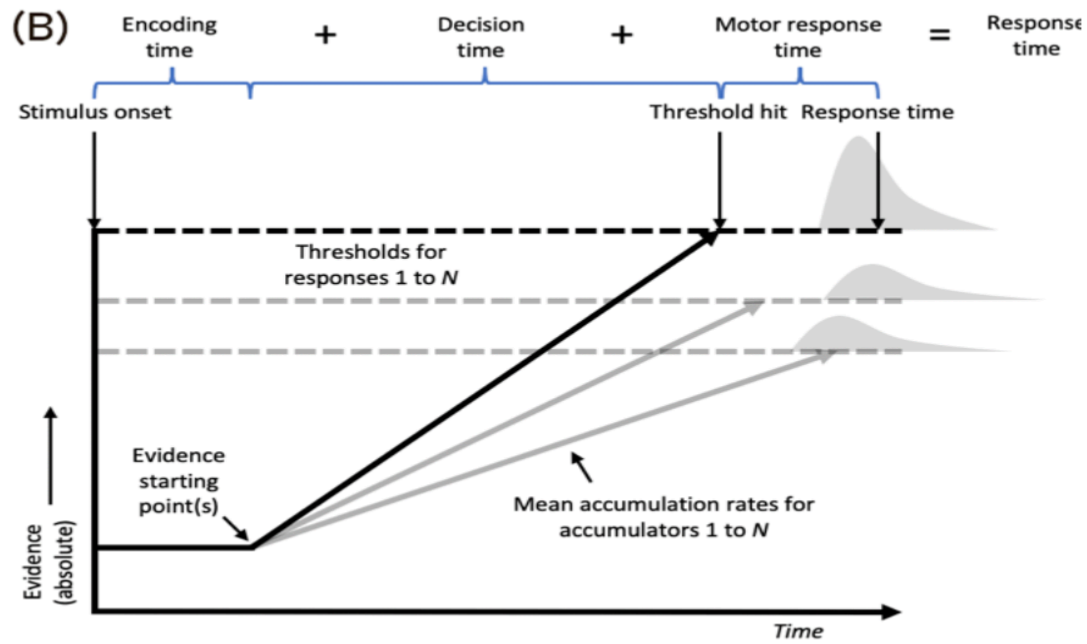


> Boag, R. J., Innes, R. J., Stevenson, N., Bahg, G., Busemeyer, J. R., Cox, G. E., … Forstmann, B. (2024, July 2). An expert guide to planning experimental tasks for evidence accumulation modelling.

Absolute Evidence Models

In **racing accumulator models** (e.g., LBA, RDM):

- Each option has its own **accumulator** tracking **absolute evidence**.
- Decision is made by the **first accumulator to reach threshold**.
- Can handle **multiple alternatives** (not just binary choices).



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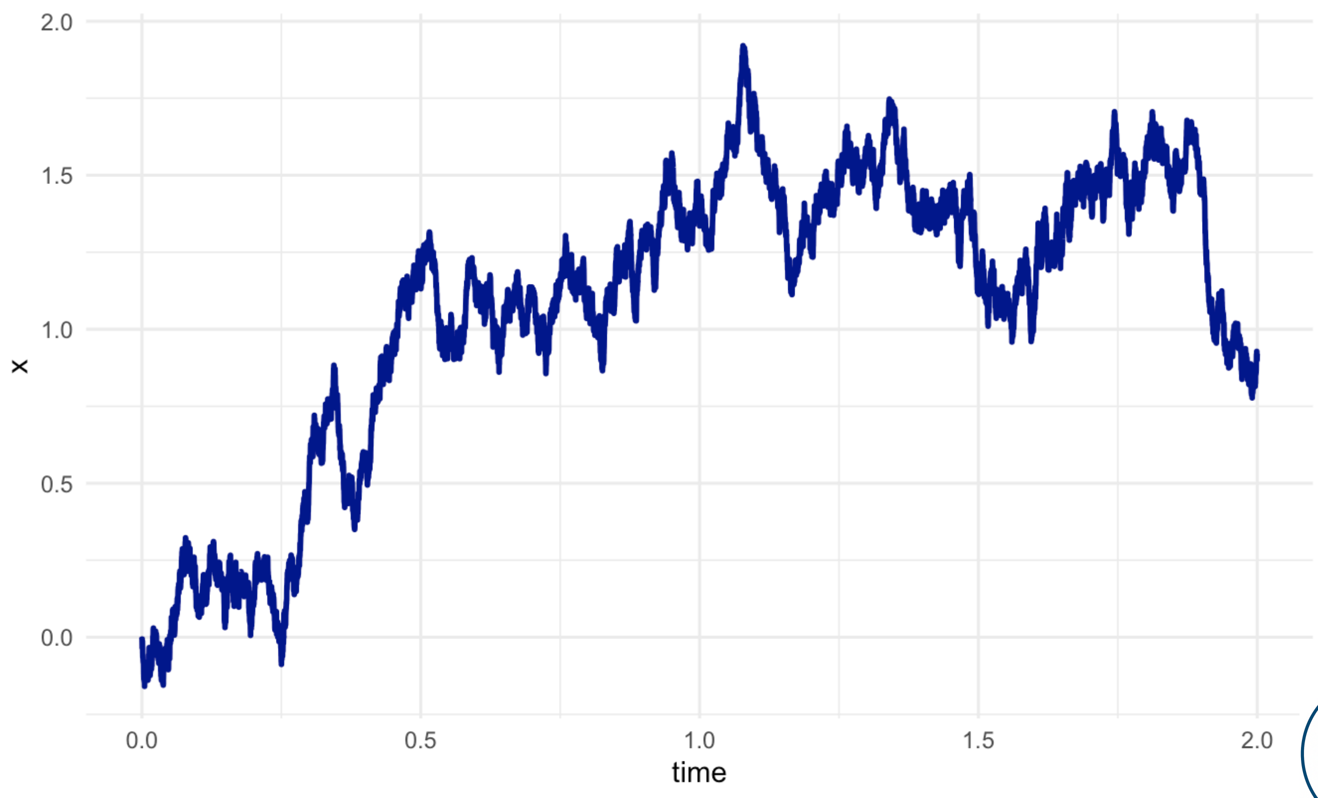
Noisy process

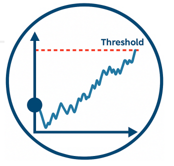
Wiener Process

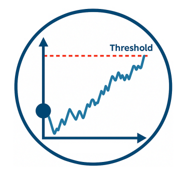
The **Wiener process** (Brownian motion) is the foundation of many decision models (Smith & Ratcliff, 2024). It models the accumulation of evidence as a noisy process:

$$x(t) = z + vt + sW(t)$$

- $x(t)$: accumulated evidence at time t
- z: starting point
- v: drift rate (signal strength)
- s: noise (standard deviation of the increments)
- $W(t)$: standard Wiener process (Gaussian increments)

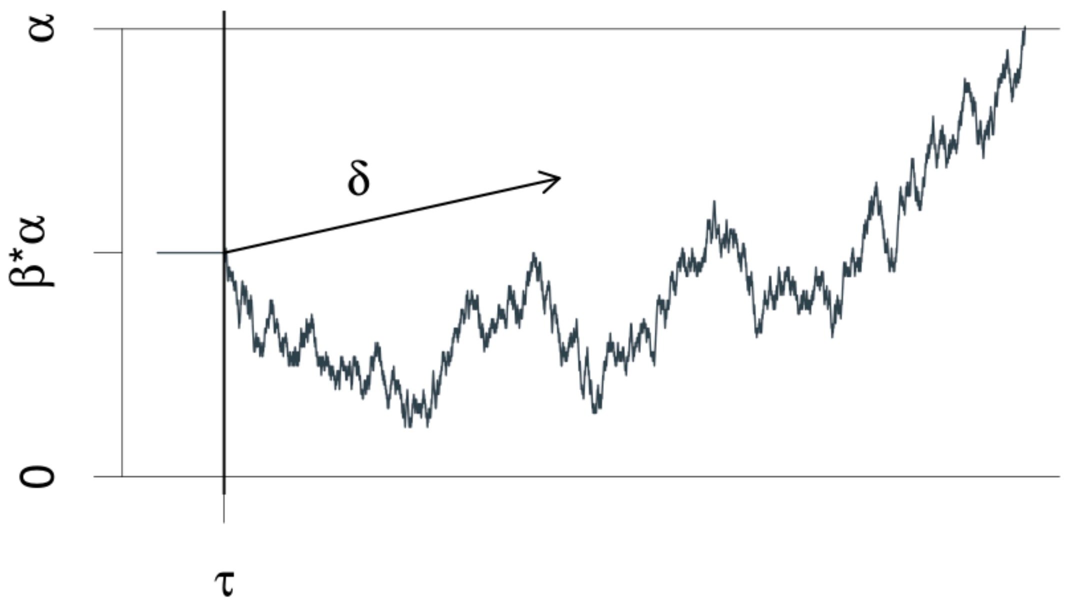





Threshold

Wiener Diffusion Model

> It is the expected distribution of the time until the process first hits or crosses one or the other boundary. This results in a bivariate distribution, over responses and hitting times.



- α : threshold
- β : initial bias (starting point)
- δ: quality of the stimulus (often υ)
- τ: non-decision time

Navarro & Fuss, 2009; Wabersich & Vandekerckhov, 2014. Copyright 2009, Joachim Vandekerckhove and Department of Psychology and Educational Sciences, University of Leuven, Belgium

Full Diffusion Decision Model

The **Full DDM** accounts for more behavioral phenomena by allowing **trial-to-trial variability** in key parameters:

Drift rate

Starting point

Non-decision time

Full DDM Parameters

a: decision boundary

z: starting point

v: drift rate

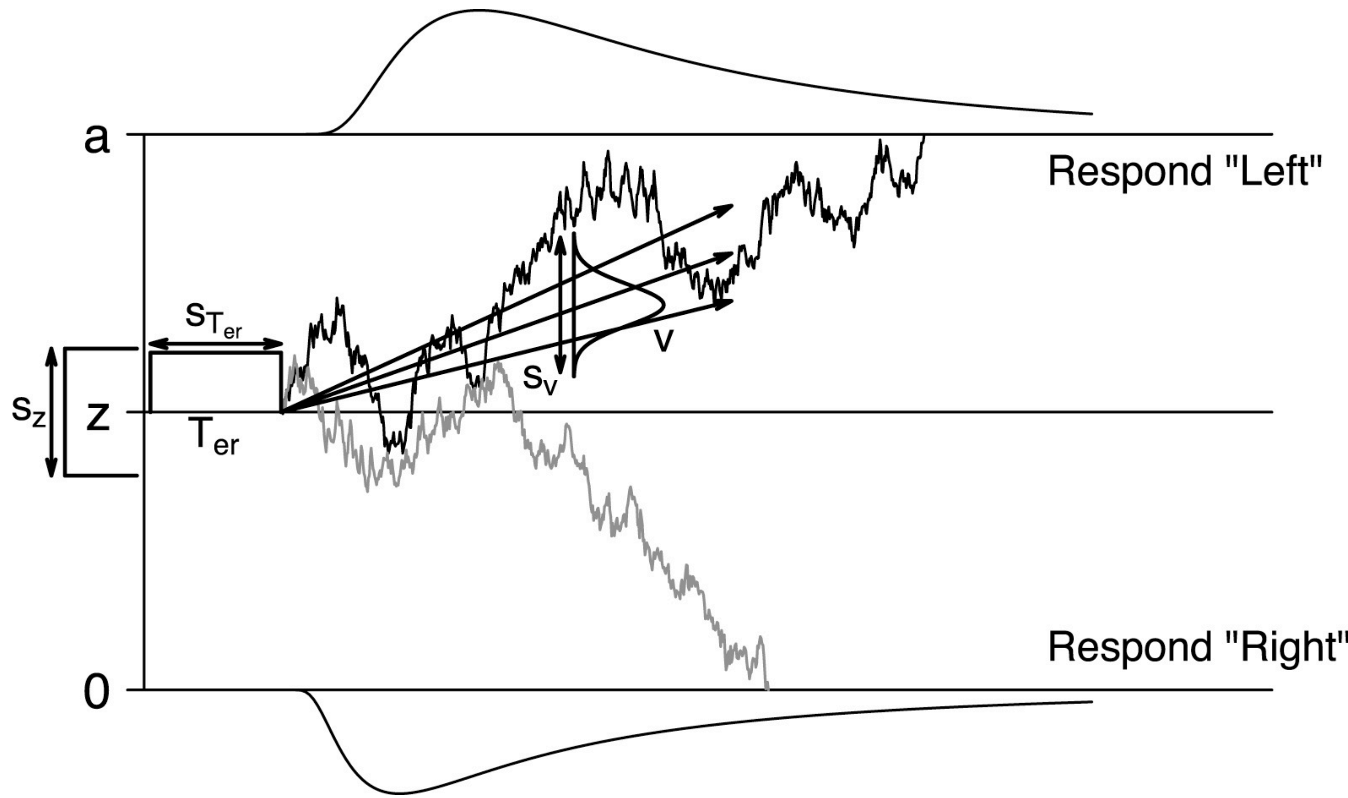
t_0: non-decision time

s: noise scale (usually fixed to 1)

η: SD of drift rate across trials

s_z: variability in start point

s_{t_0}: variability in non-decision time



> Boehm, U., Annis, J., Frank, … & Wagenmakers, E. J. (2018). Estimating across-trial variability parameters of the Diffusion Decision Model: Expert advice and recommendations. *Journal of Mathematical Psychology*, 87, 46-75. Ratcliff, R., & Rouder, J. N. (1998). Modeling Response Times for Two-Choice Decisions. Psychological Science, 9(5), 347-356.

Purpose of variability

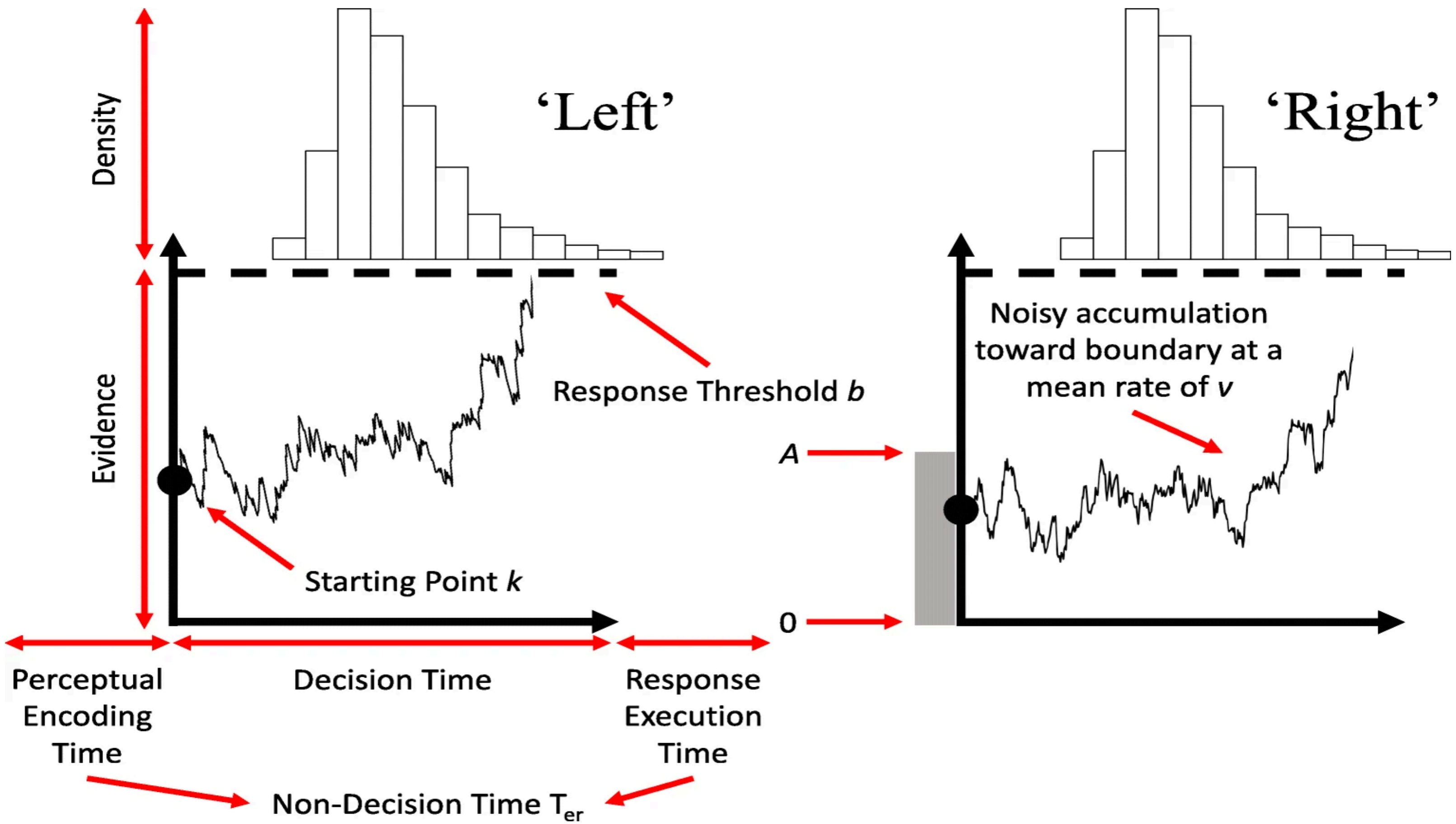
Adding variability improves the model's ability to:

- Capture **error RT differences**
- Reflect **trial-to-trial attention or difficulty changes**

However, it increases computational demands.

Racing Diffusion Model

Instead of a single process choosing between boundaries, the RDM uses **multiple independent diffusion processes**, one per option. Each accumulator races toward its threshold. The first to cross **wins.** Tillman, Van Zandt, & Logan, 2020



Summary

Model	Core Mechanism	Key Strengths
Wiener	Noisy accumulation	Simple FPT, binary outcomes
Full DDM	Accumulation + param variability	Realistic RTs, error patterns
Racing DM	Multiple accumulators	Handles multi-alternative decisions

Core assumptions of the basic EAM

- Each decision = a **single, continuous accumulation** of evidence
- Culminates in a **discrete response**
- Evidence accumulates from **stimulus onset to response**

Guidelines

Boag et al. 2025

Within-Trial Stationarity

Model parameters are **fixed within a trial**

Evidence accumulation:

- Constant **mean rate**, though noisy
- No changes in stimulus evidence mid-trial

Decision thresholds:

- Set **before** stimulus onset
- **Do not change** during the trial

Within-Condition Stationarity

Parameters are constant **across same-type trials**

Assumes:

- Trials of same condition reflect **same cognitive settings**
- Participant behavior is stable

Free of contaminant processes

Data should reflect **evidence accumulation**!

Avoid:

- Random guessing
- Fast guesses
- Attention lapses or missing responses

> Clean data = better model fit and interpretability.

“All models are wrong, but some are useful” - G. Box

Thank you!