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**SENSE<sub>x</sub> LAB**

SISSA Explorations of the Neuronal foundations of Sensory Experience

Univ TS Master in Neuroscience  
April 15, 2025

# SENSE<sub>x</sub> LAB

SISSA Explorations of the Neuronal foundations of Sensory Experience

*How do we go about exploring  
the neuronal foundations of  
sensory experience?*

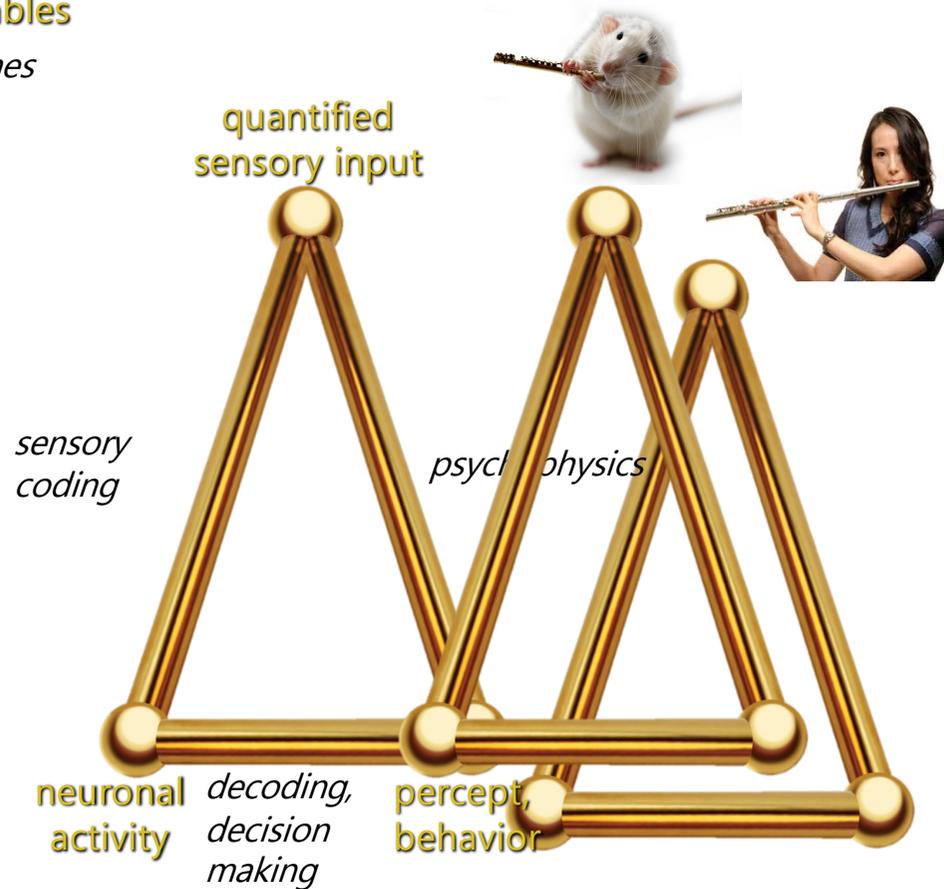
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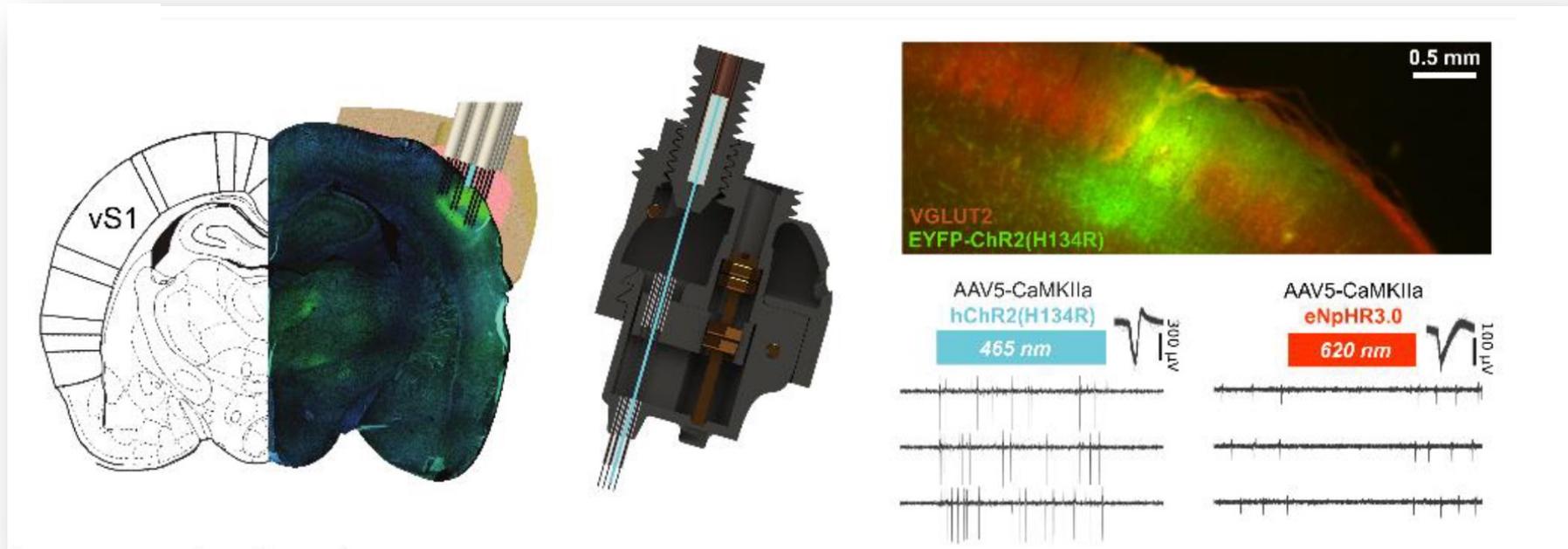
*How do we go about exploring the neuronal foundations of sensory experience?*

Experimental variables

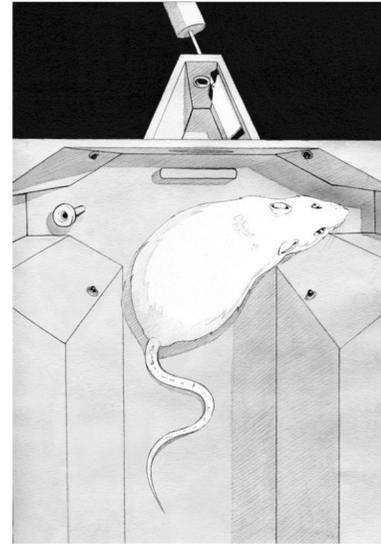
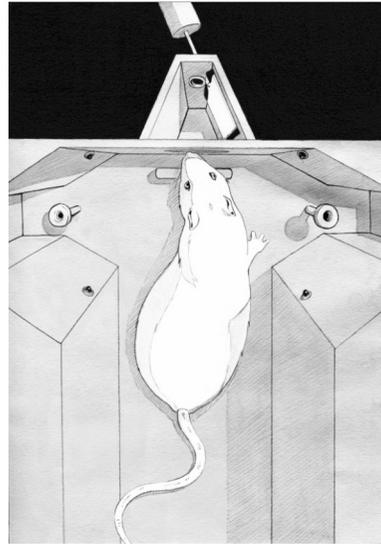
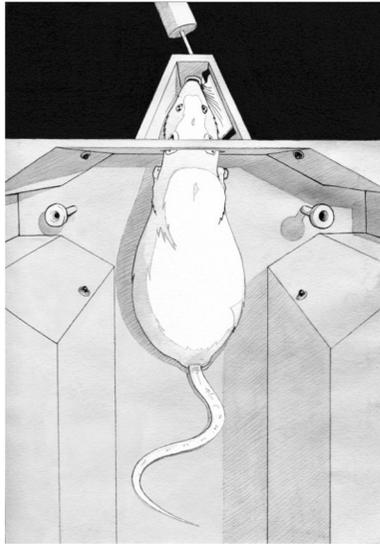
*Strategies, approaches*

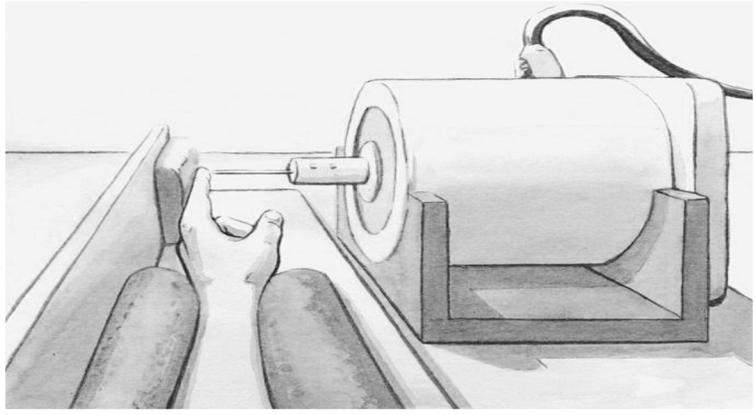




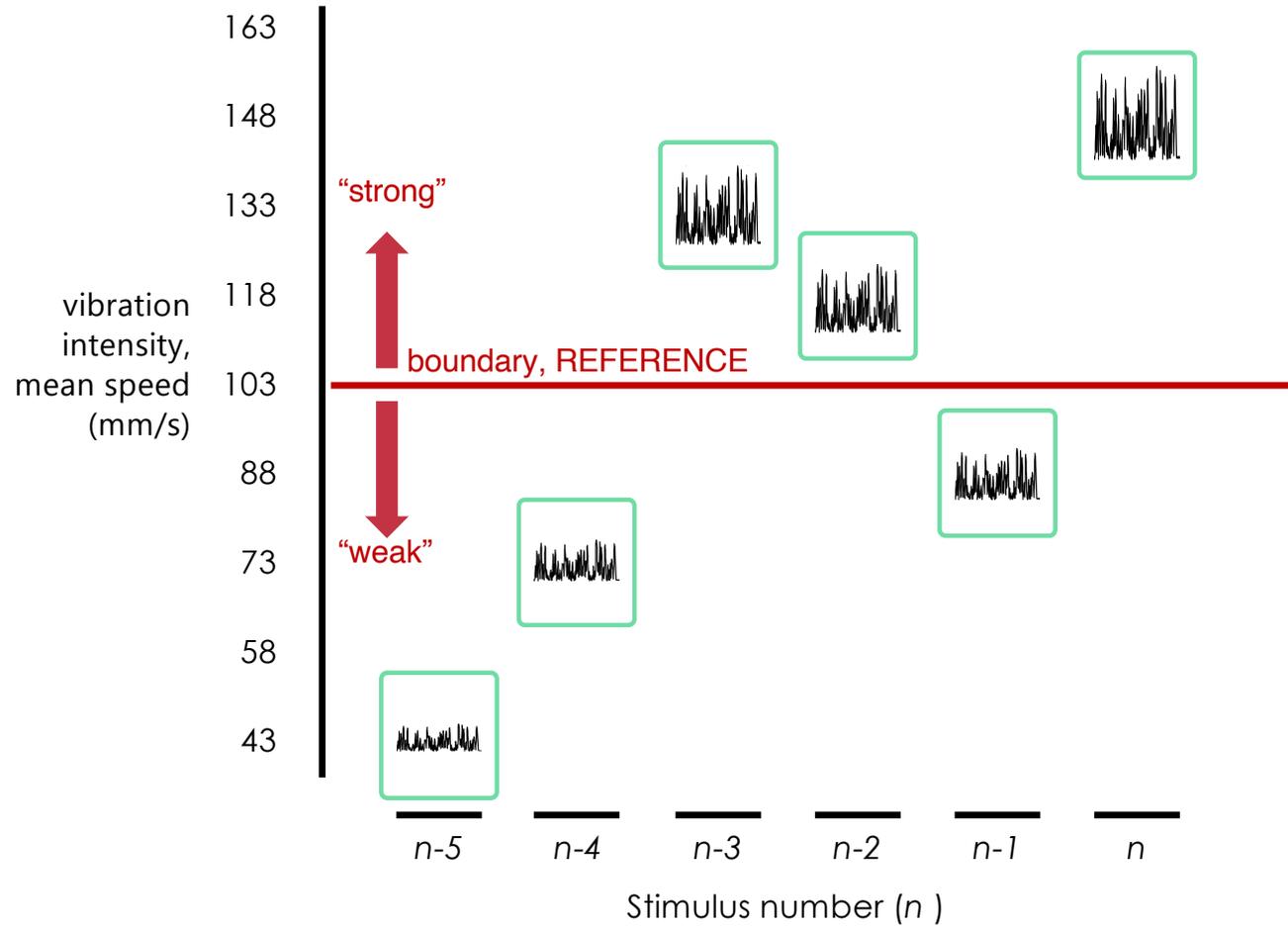


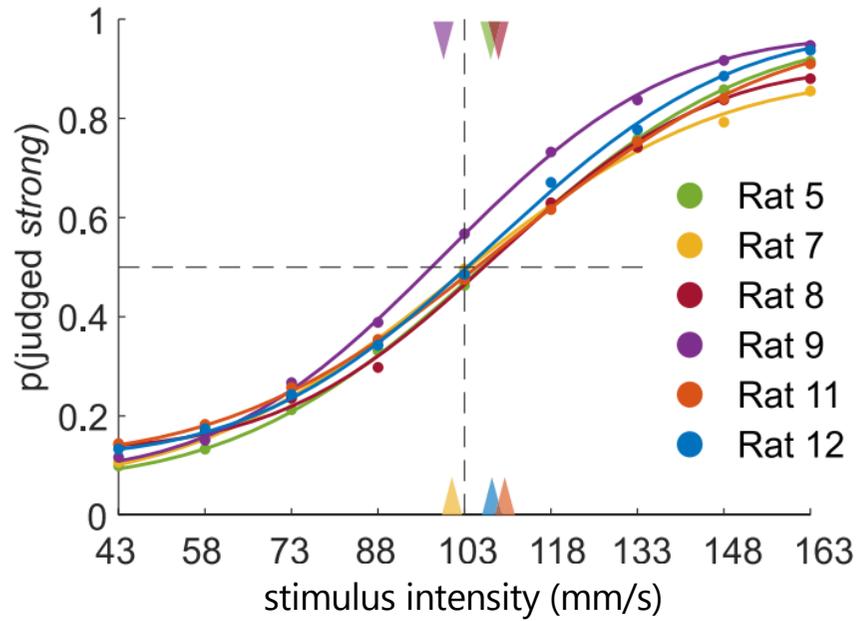
Reinartz, S., Fassihi, A., Ravera, M., Paz, L., Pulecchi, F., Gigante, M., and Diamond, M.E. (2024)  
*Direct contribution of the sensory cortex to the judgment of stimulus duration*  
**Nature Communications**



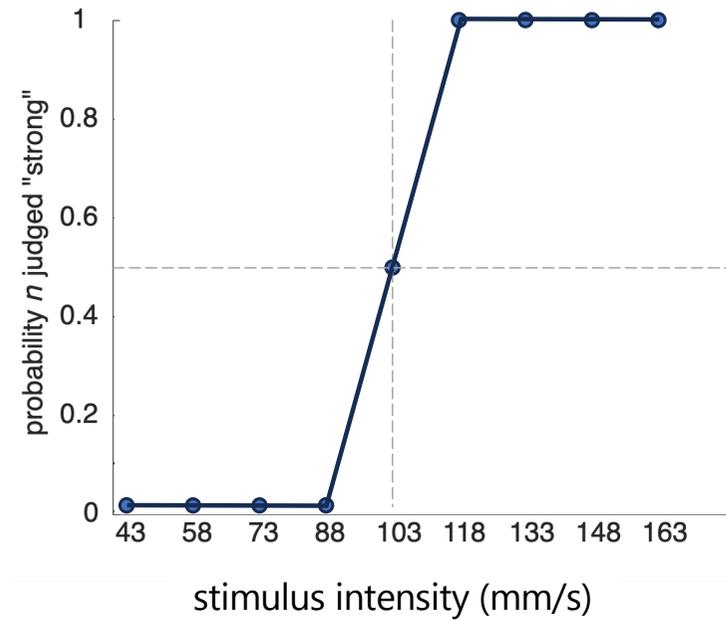


# REFERENCE MEMORY



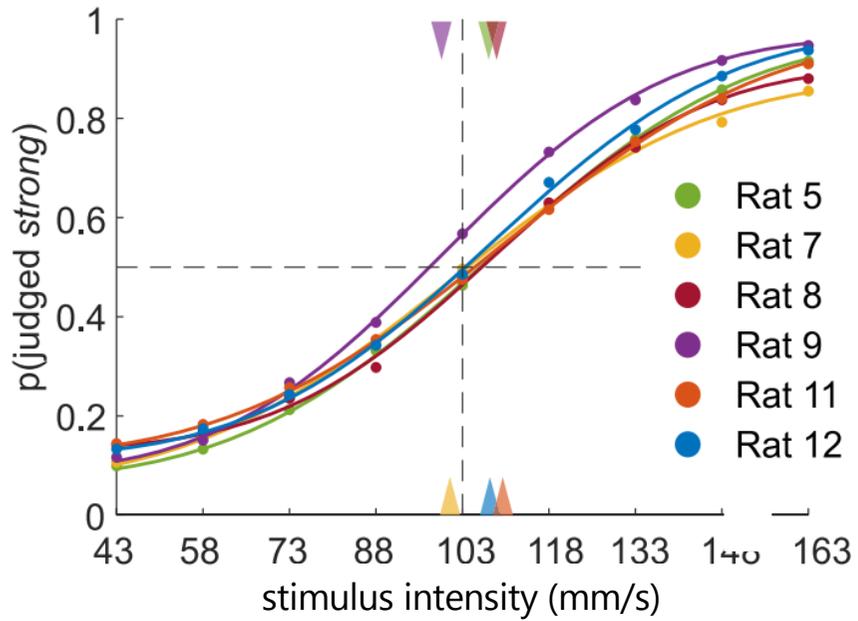


the perfect, "ideal" subject

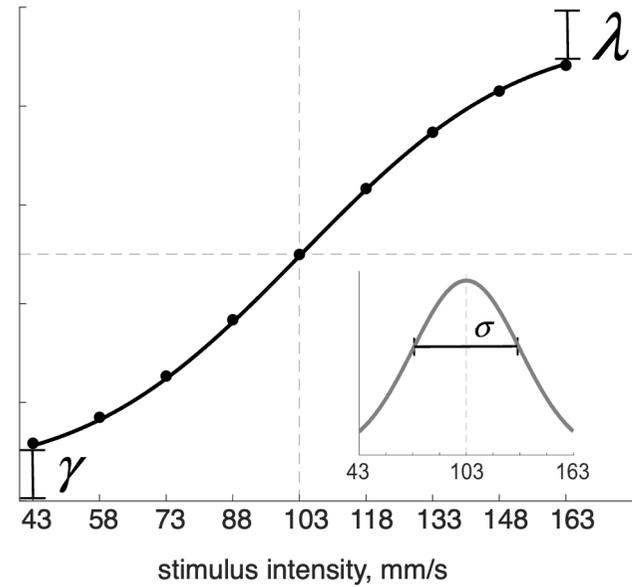
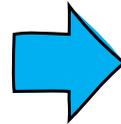


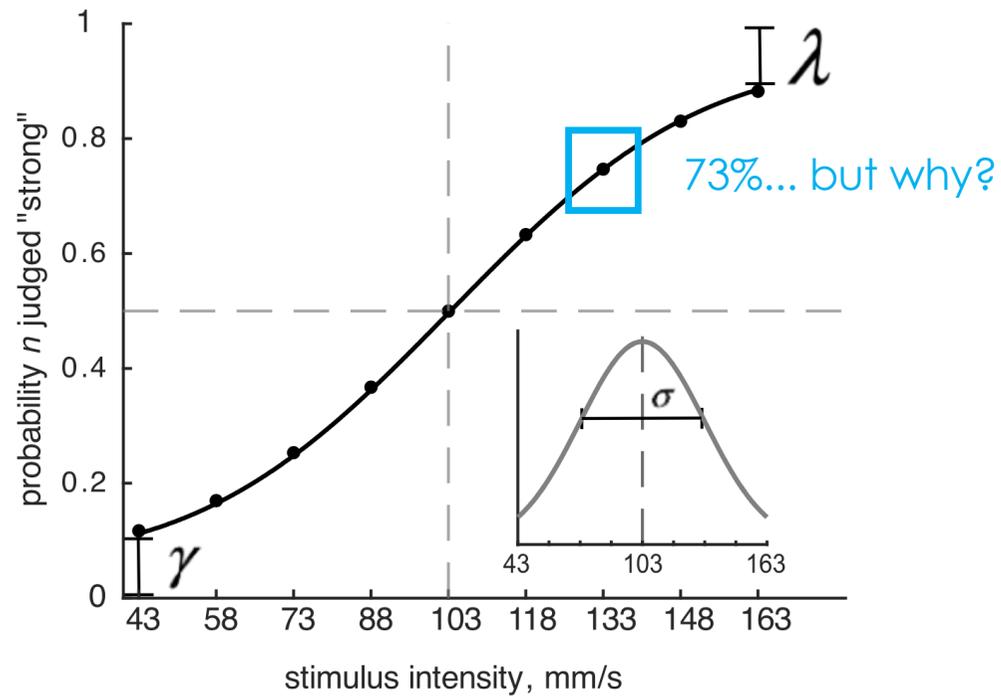
Hachen, I., Reinartz, S., Brasselet, R., Stroligo, A., and Diamond, M.E. (2021).  
*Dynamics of history-dependent perceptual judgment.*  
**Nature Communications**

# psychometric measure of behavior



$$p(\text{strong})_n = \gamma + (1 - \gamma + \lambda) \cdot 1/2 \left[ 1 + \operatorname{erf} \left( \frac{\text{intensity}_n - \mu_n}{\sigma\sqrt{2}} \right) \right]$$



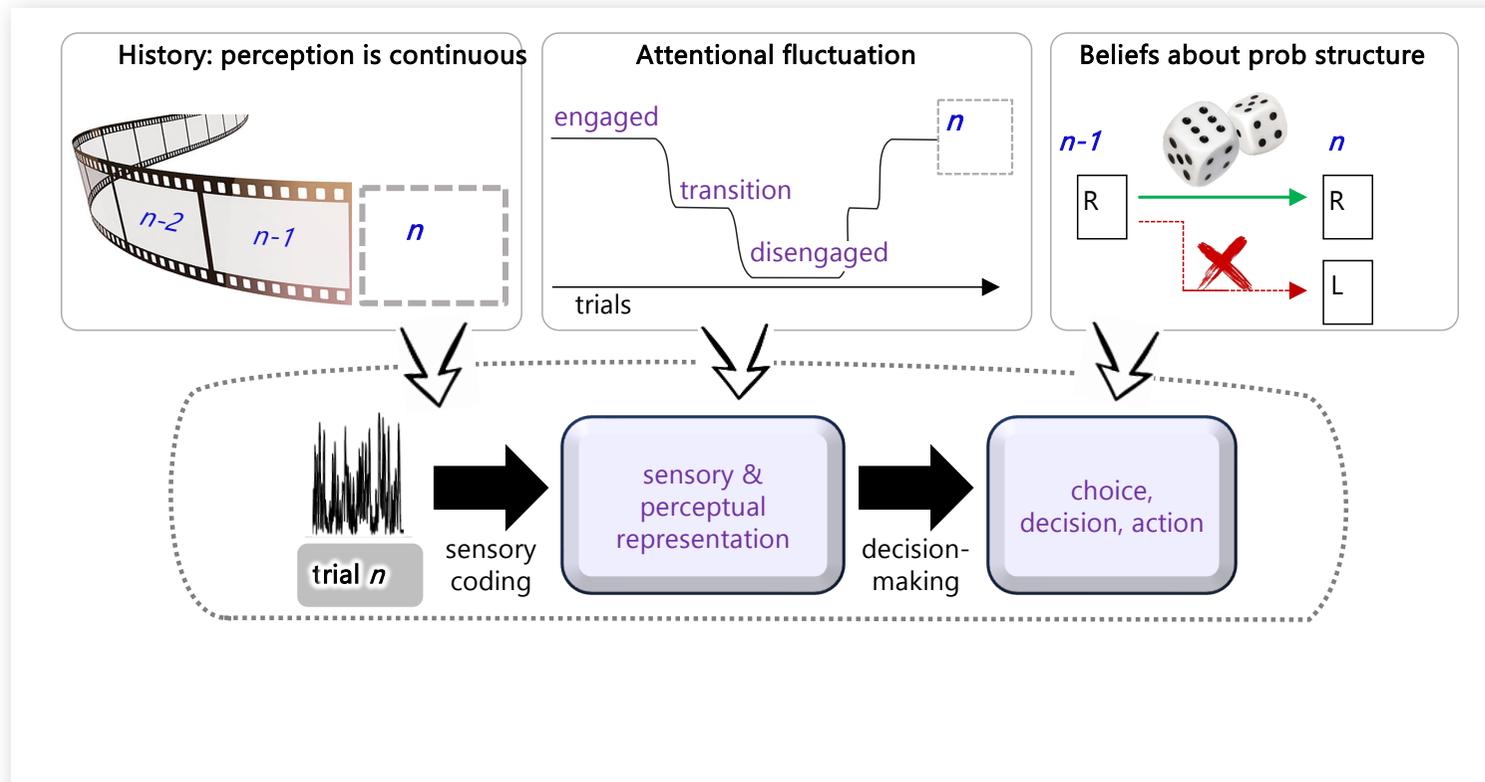


Psychometric curves are built from choices averaged over many trials.

*But it is the single choice that may save (or not) your life.*

...like assessing motion flow in traffic

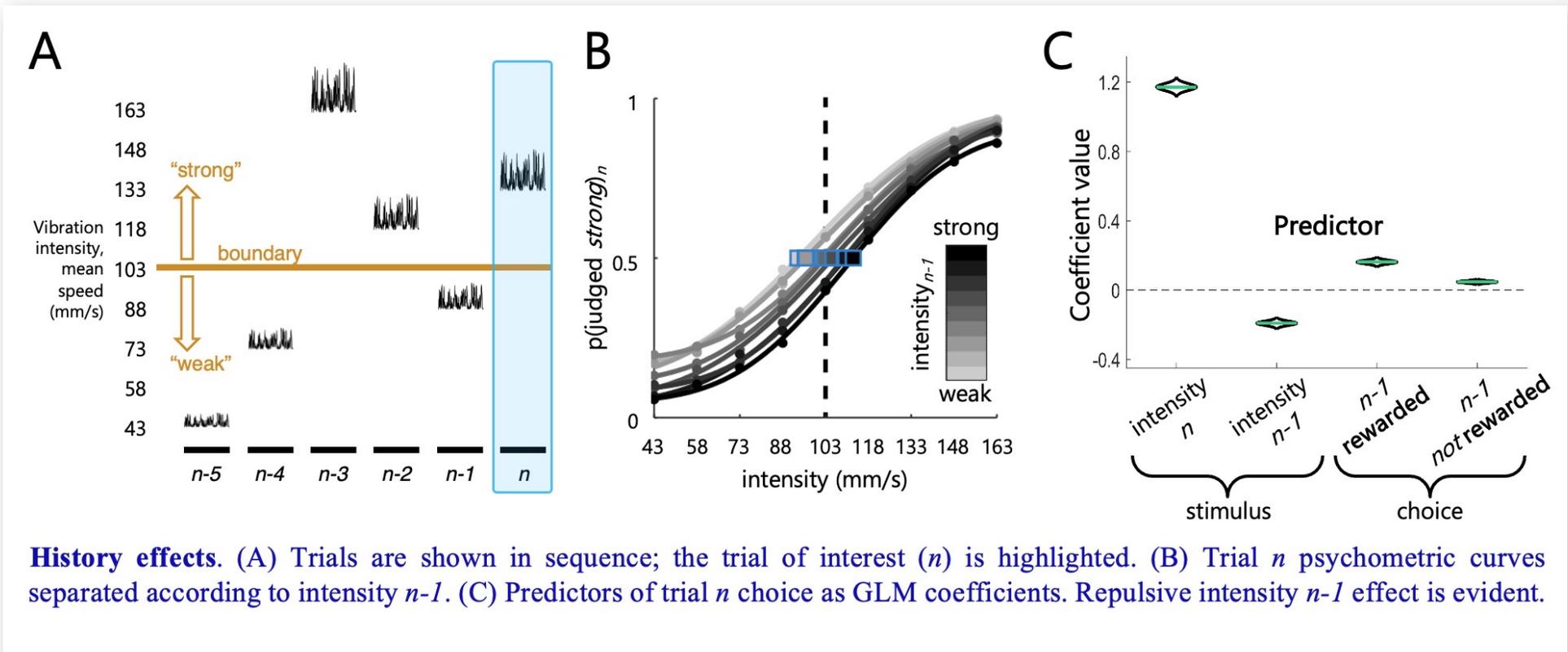


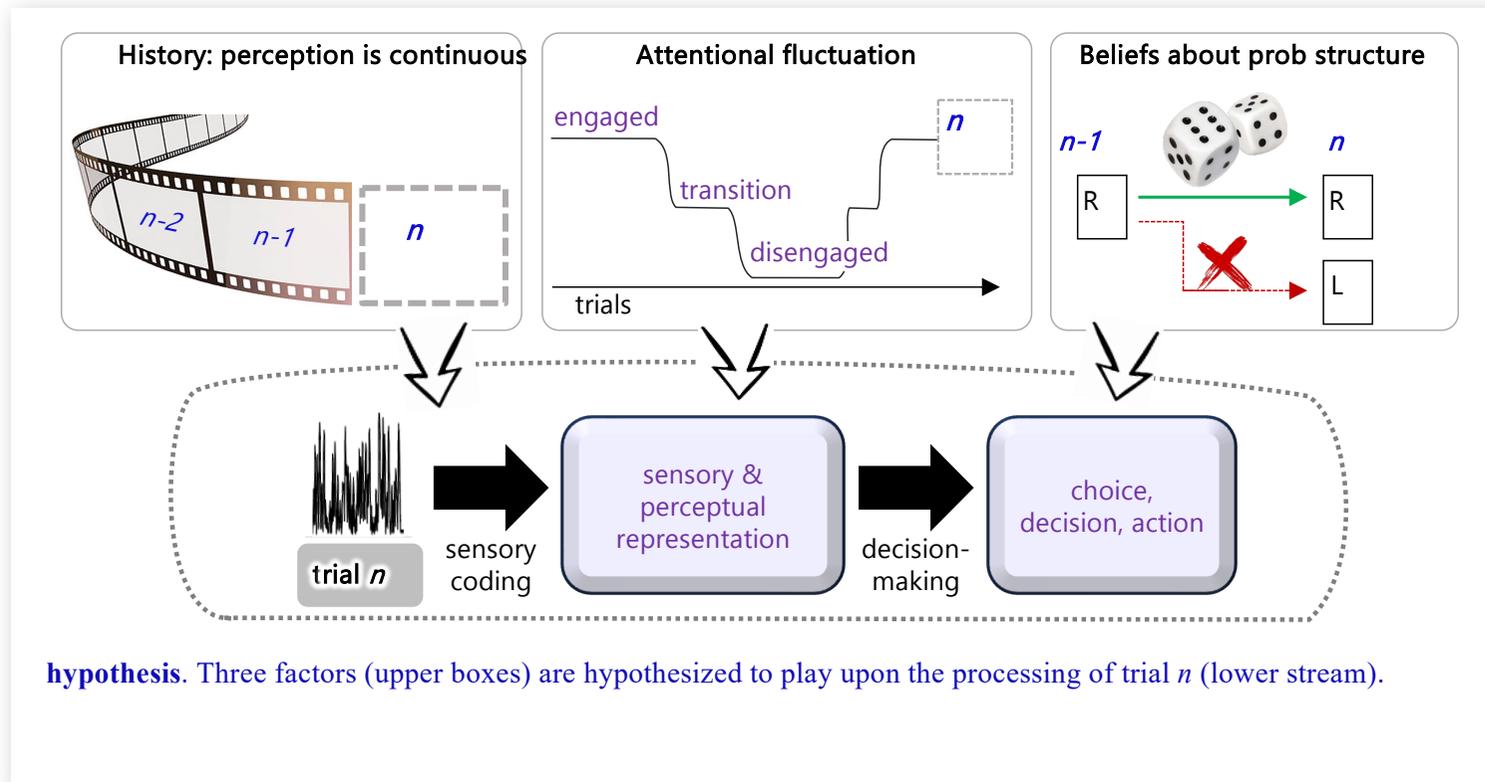


### HYPOTHESIS

- Trial  $n$  sensory information (lower stream) is transmitted to downstream regions where a transformation to decision and action is executed.
- Three separable factors (upper stream) interact with this processing stream and, together, account for most of the trial-to-trial choice variability enacted on that stimulus input.

What do we mean by "history"?





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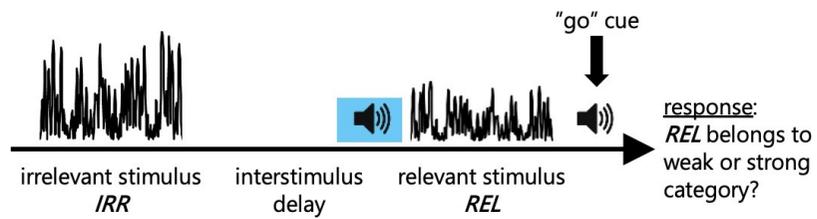
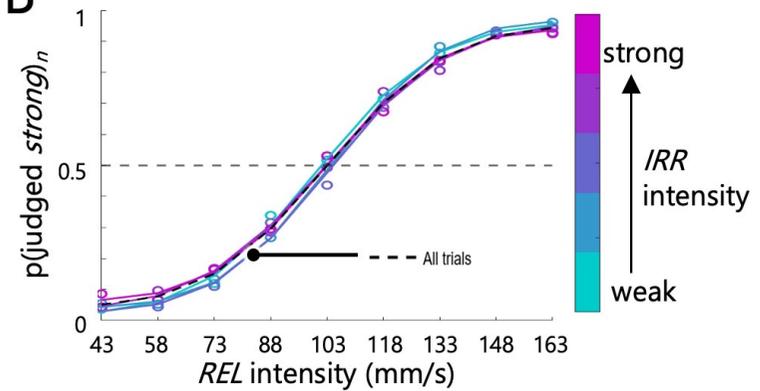
What do we mean by “attentional fluctuation”?

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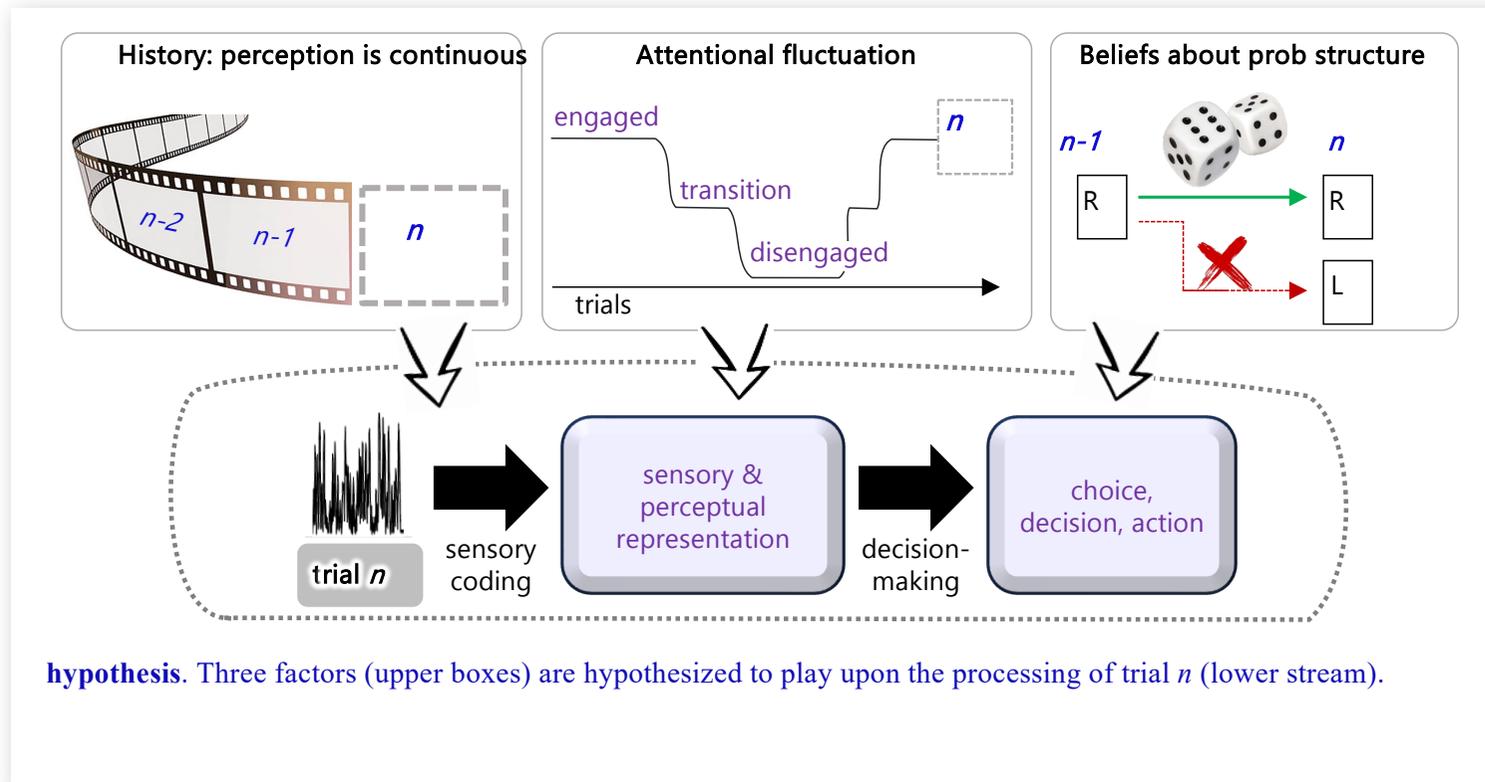


we all flake out from time to time...

... but to understand the mechanisms of single choices, we need to treat attention *not* as a spontaneous fluctuation but as a controlled experimental variable

**A****B**

**Attention under experimental control.** (A) The task-relevant stim (*REL*) is preceded by an irrelevant distractor (*IRR*). Blue icon represents acoustic cue to attend to *REL*. (B) Psychometric curves, separated by *IRR* intensity. Because the judgment of *REL* is unaffected by *IRR* intensity, we conclude that this rat could successfully ignore *IRR*.

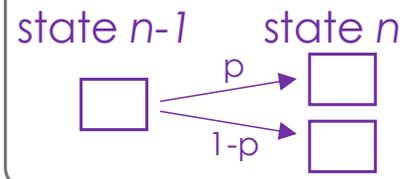


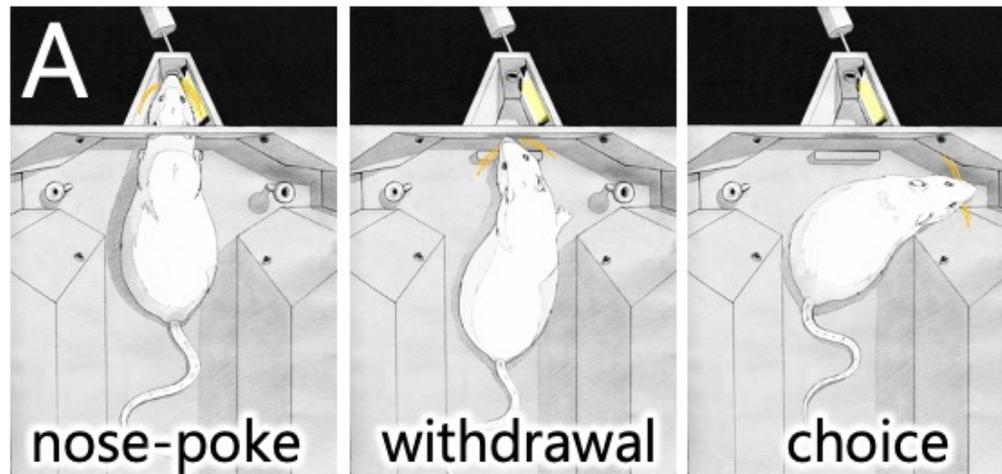
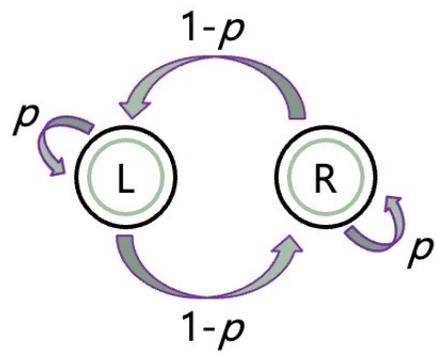
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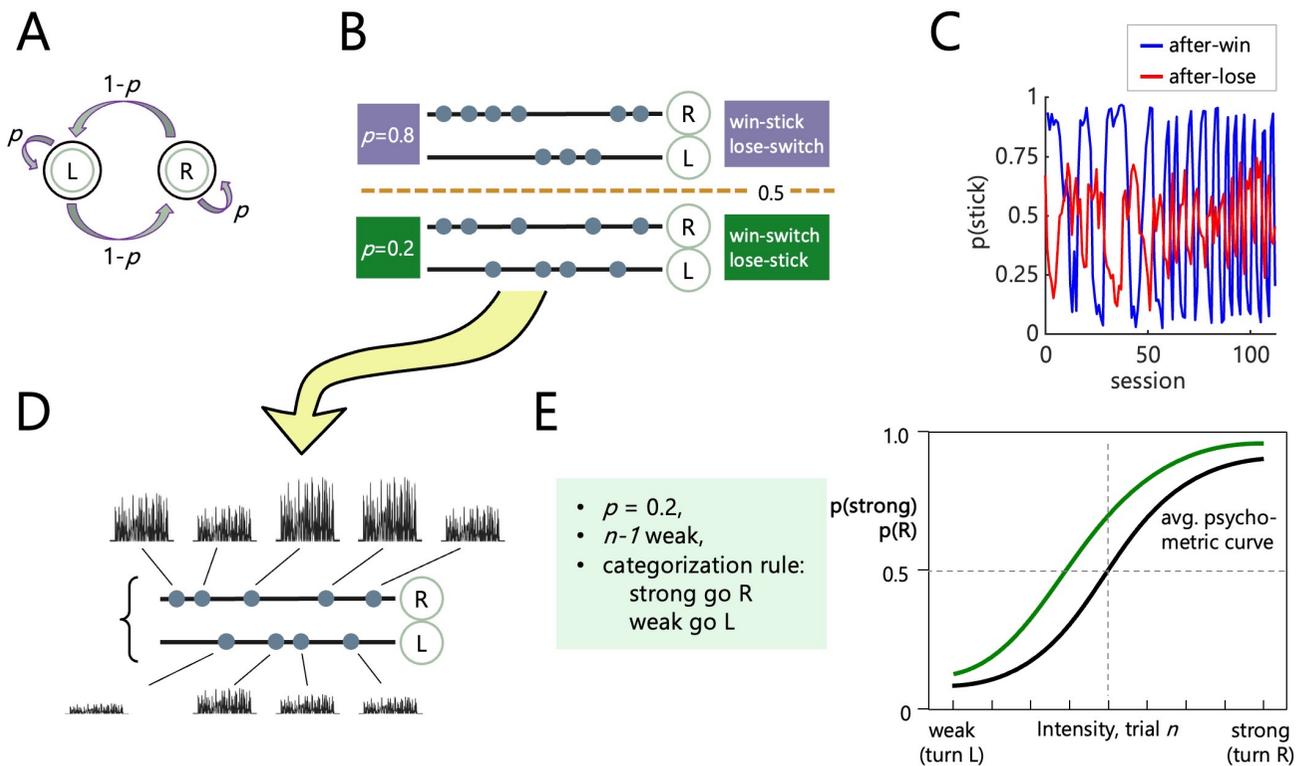
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What do we mean by “Beliefs about probability structure”?

beliefs about  
environmental  
structure

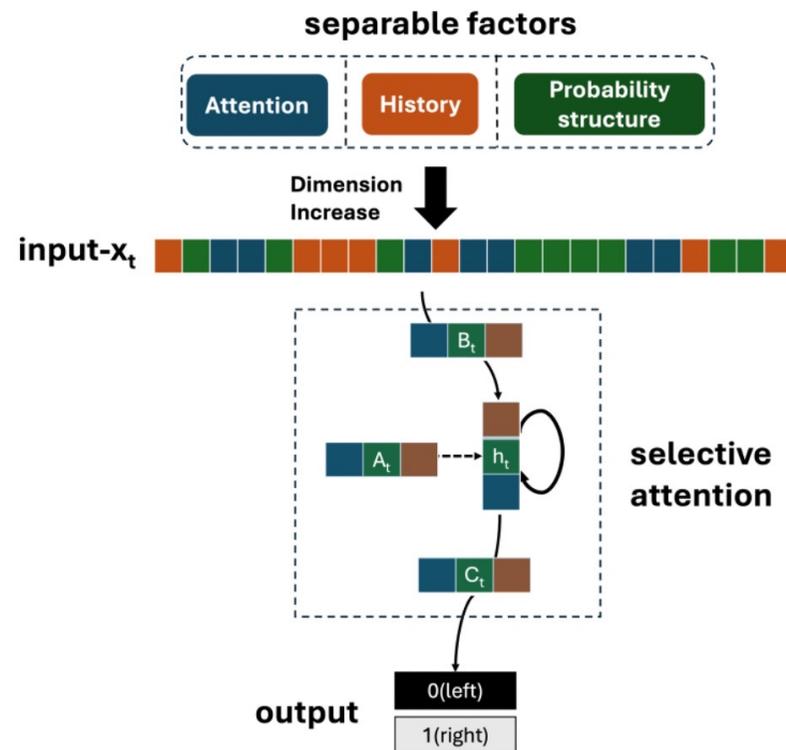






**Beliefs about probabilistic structure.** (A) Markov chain for states of L and R baited. (B)  $p = 0.8$  (upper) tends to generate strings of repeating baited side;  $p = 0.2$  (lower) strings of alternating baited side. Optimal decision strategies in boxes at the right. (C) Pilot experiment: zig-zag appearance is the adaptation of decision strategy: high  $p(\text{stick})$  after-win and low  $p(\text{stick})$  after-lose in sessions with  $p = 0.8$ , and the opposite in sessions with  $p = 0.2$ . After 50 sessions, frequency of  $p$  switching increases. (D) For the combined Markov chain/sensory perception experiment, tactile stimuli are imposed on the L/R sequence. Example:  $p = 0.2$ , R and L are strong and weak reward sides, respectively. (E) Sensory evidence meets prediction. The conditions given in green box would bias the rat towards choose the R reward spout. Thus, the single-trial psychometric curve (green) would be shifted to the left with respect to the average curve over all trials (black).

**Deep State Space Model.** In this simplified depiction, the same three factors shown in the preceding figure now serve as inputs to the model, which can be trained to generate an output matching observed behavioral data. The representations within the dashed box are interrogated to understand the processing within the model.



## Projects and competencies gained

In general, the projects concern the exploration of the neuronal foundations of sensory experience, with specific projects being variants within the framework illustrated in the presentation.

### Humans

#### *Projects*

- perceptual decision making
- exploration of probability structure

#### *Competencies gained*

- management of human subject recruitment
- executing human neuroscience
- computational neuroscience, including psychometric curve functions

### Domain non-specific

- theoretical neuroscience, deep learning models, relation of artificial intelligence to natural intelligence

\*to directly participate in experiments with rats, students need to complete certification through relevant courses

### \* Rats

#### *Projects*

- perceptual decision making
- CCL11-antibody approach to restoring cognitive function

#### *Competencies gained*

- training and testing rats; running experiment software
- data analysis
- computational neuroscience, including psychometric curve functions
- advanced stage: Neuropixel recording and optogenetics

... beautiful research group

