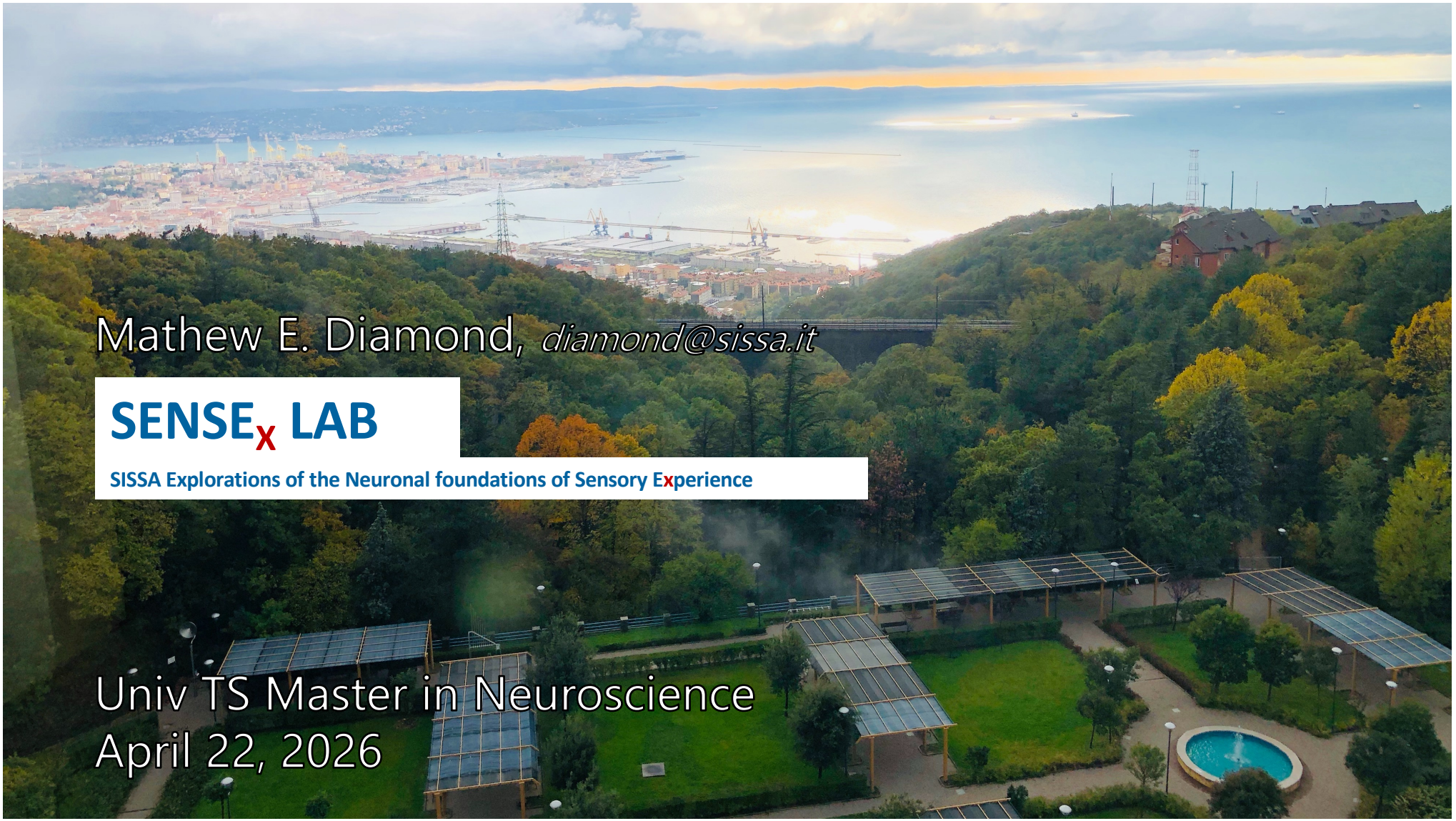


Mathew E. Diamond, *diamond@sissa.it*

SENSE$_X$ LAB

SISSA Explorations of the Neuronal foundations of Sensory Experience

Univ TS Master in Neuroscience
April 22, 2026

SENSE$_X$ LAB

SISSA Explorations of the Neuronal foundations of Sensory Experience

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

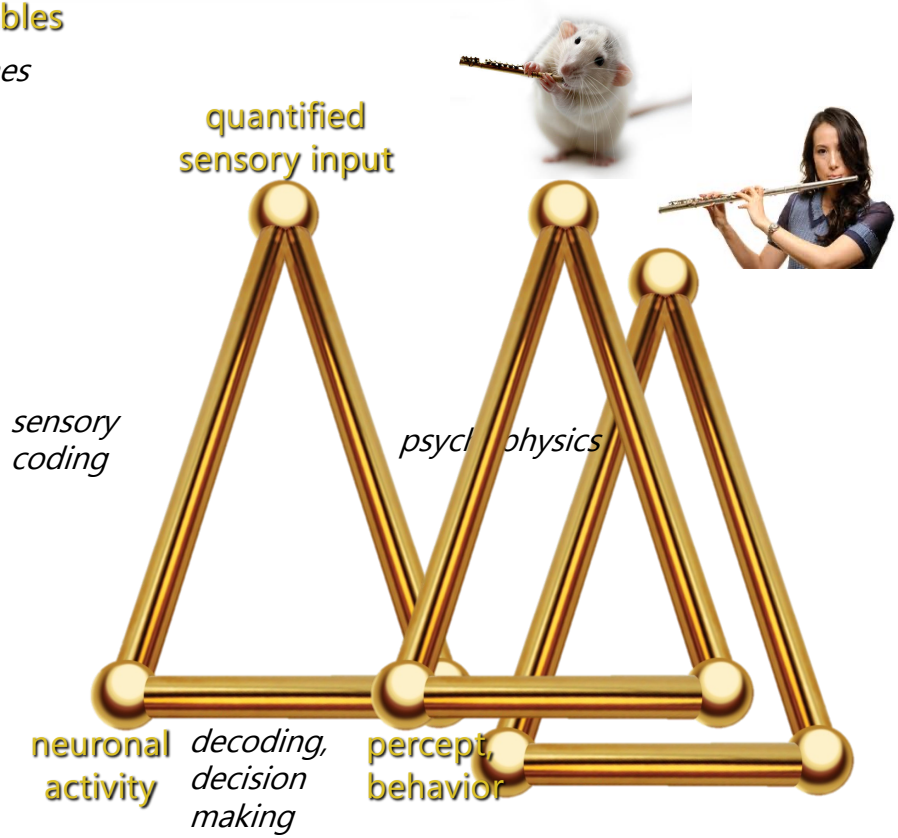
SENSE$_X$ LAB

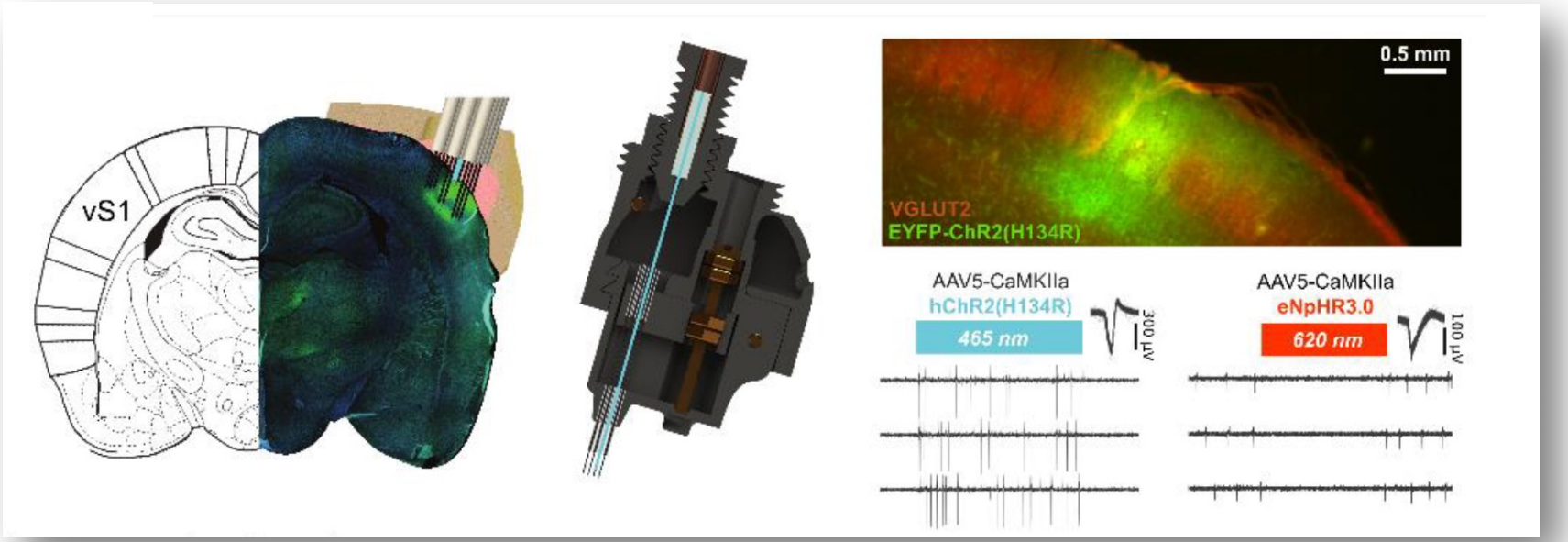
SISSA Explorations of the Neuronal foundations of Sensory Experience

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

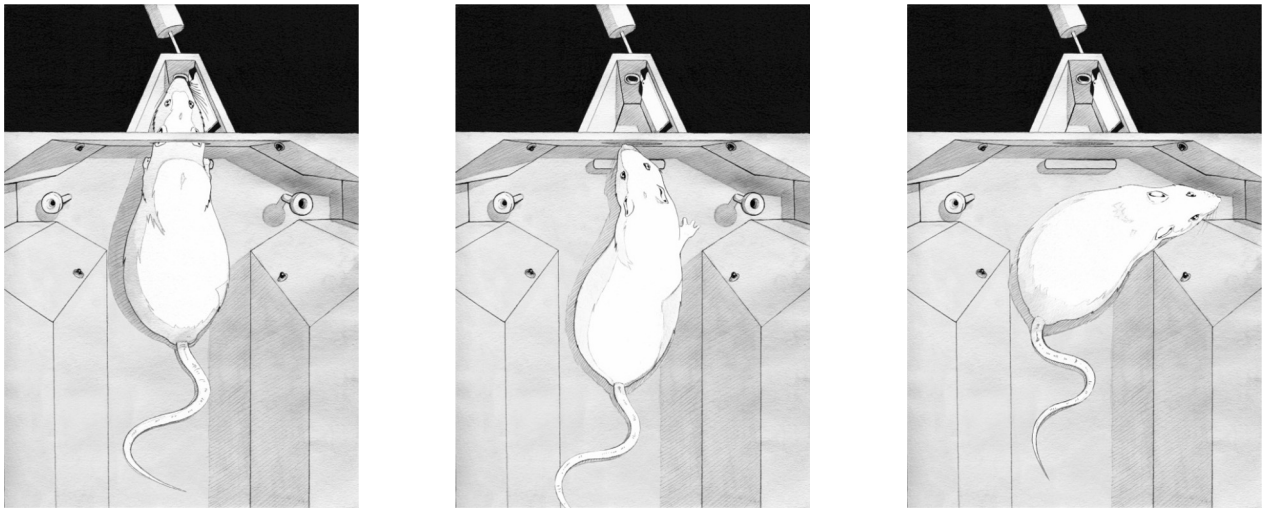
Experimental variables

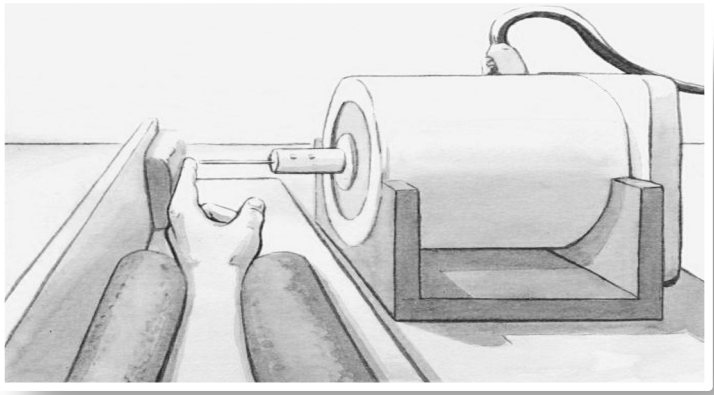
Strategies, approaches

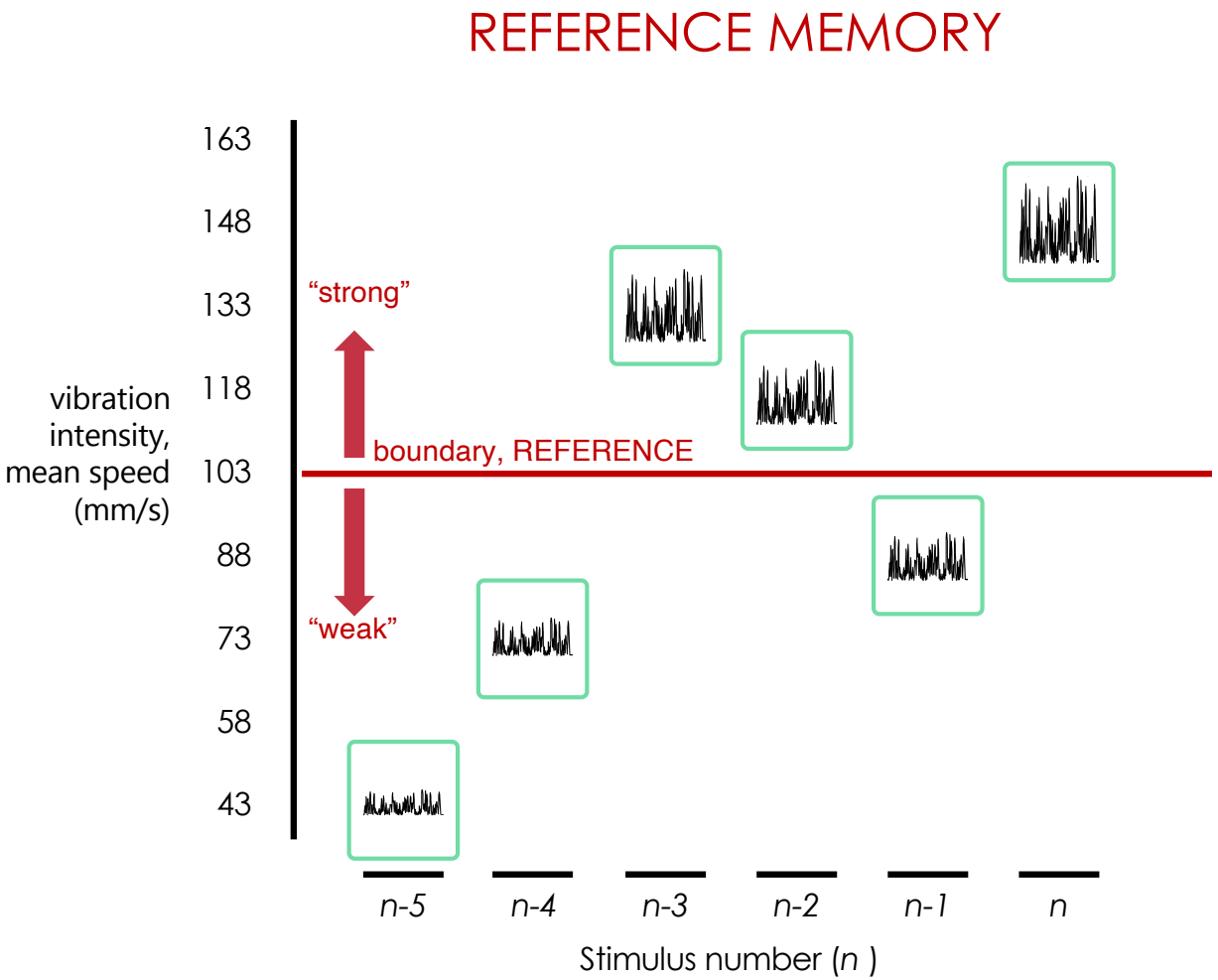


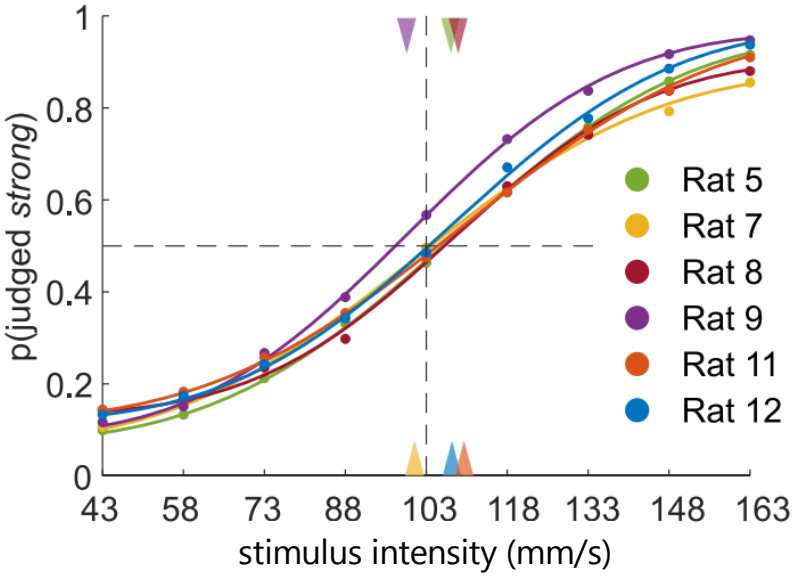


Reinartz, S., Fassihi, A., Ravera, M., Paz, L., Pulecchi, F., Gigante, M., and Diamond, M.E. (2024)
Direct contribution of the sensory cortex to the judgment of stimulus duration
Nature Communications

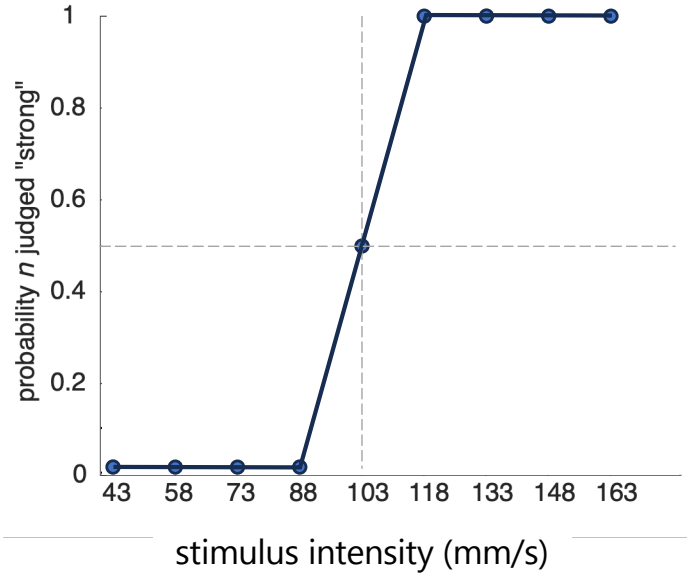





REFERENCE MEMORY
163
148
133
118
103
88
73
58
43
vibration intensity, mean speed (mm/s)
"strong"
"weak"
boundary, REFERENCE
n-5
n-4
n-3
n-2
n-1
n
Stimulus number (n)



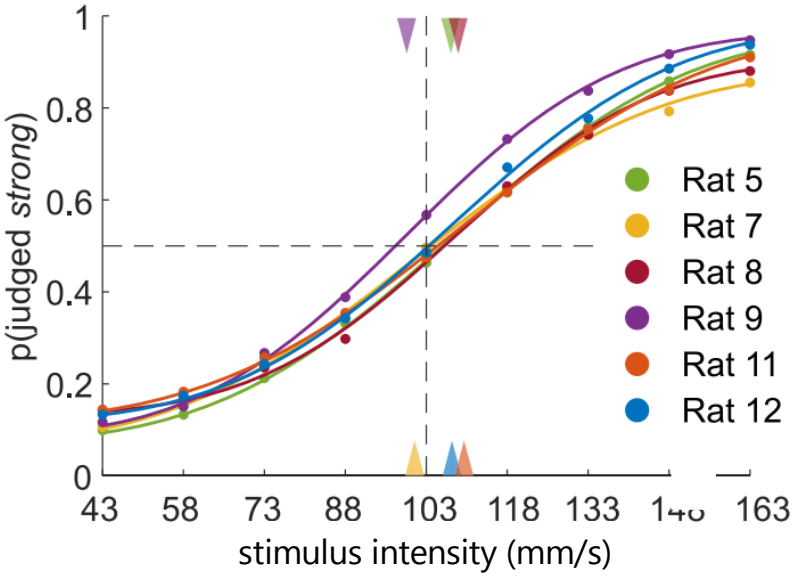
the perfect, "ideal" subject

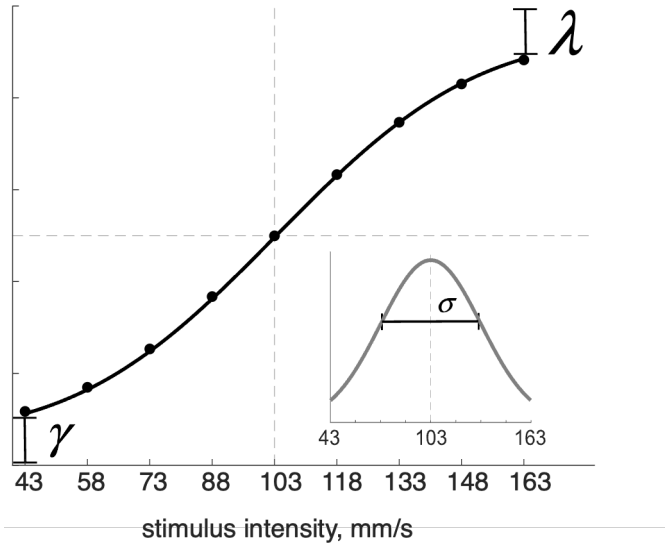


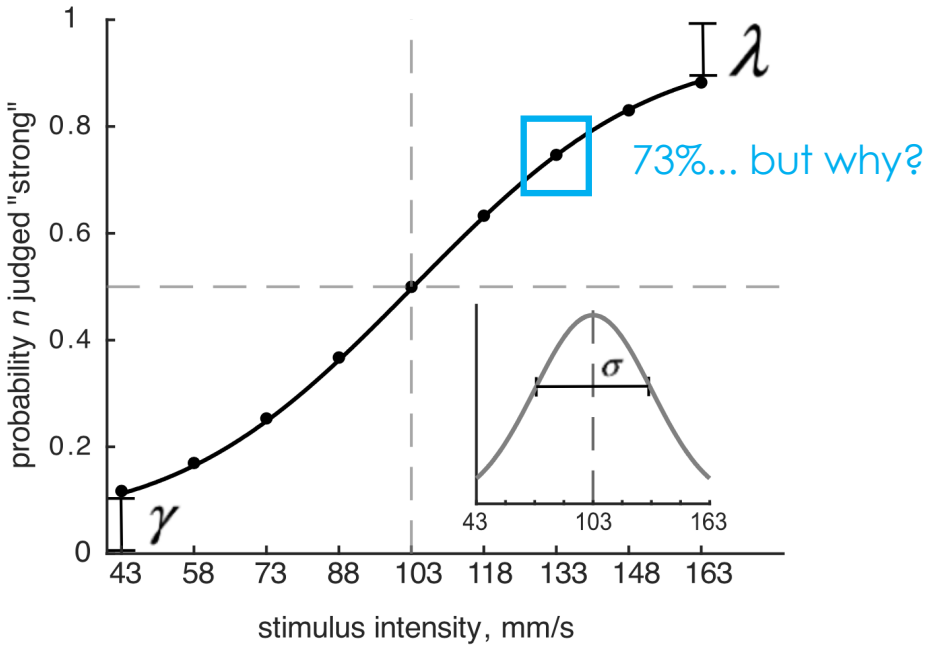
Hachen, I., Reinartz, S., Brasselet, R., Stroligo, A., and Diamond, M.E. (2021).
Dynamics of history-dependent perceptual judgment.
Nature Communications

psychometric measure of behavior

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





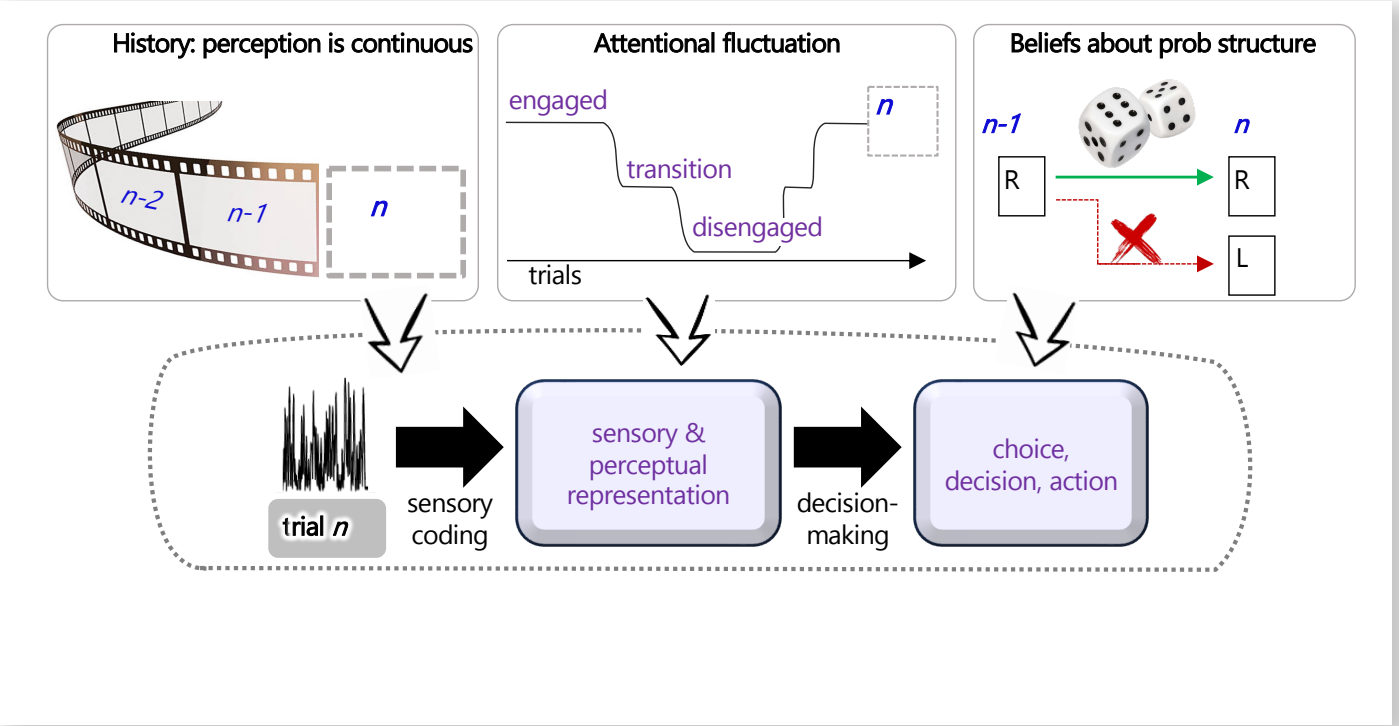

1
0.8
0.6
0.4
0.2
0
probability n judged "strong"
λ
γ
σ
43
103
163
43
58
73
88
103
118
133
148
163
stimulus intensity, mm/s
73%... but why?

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

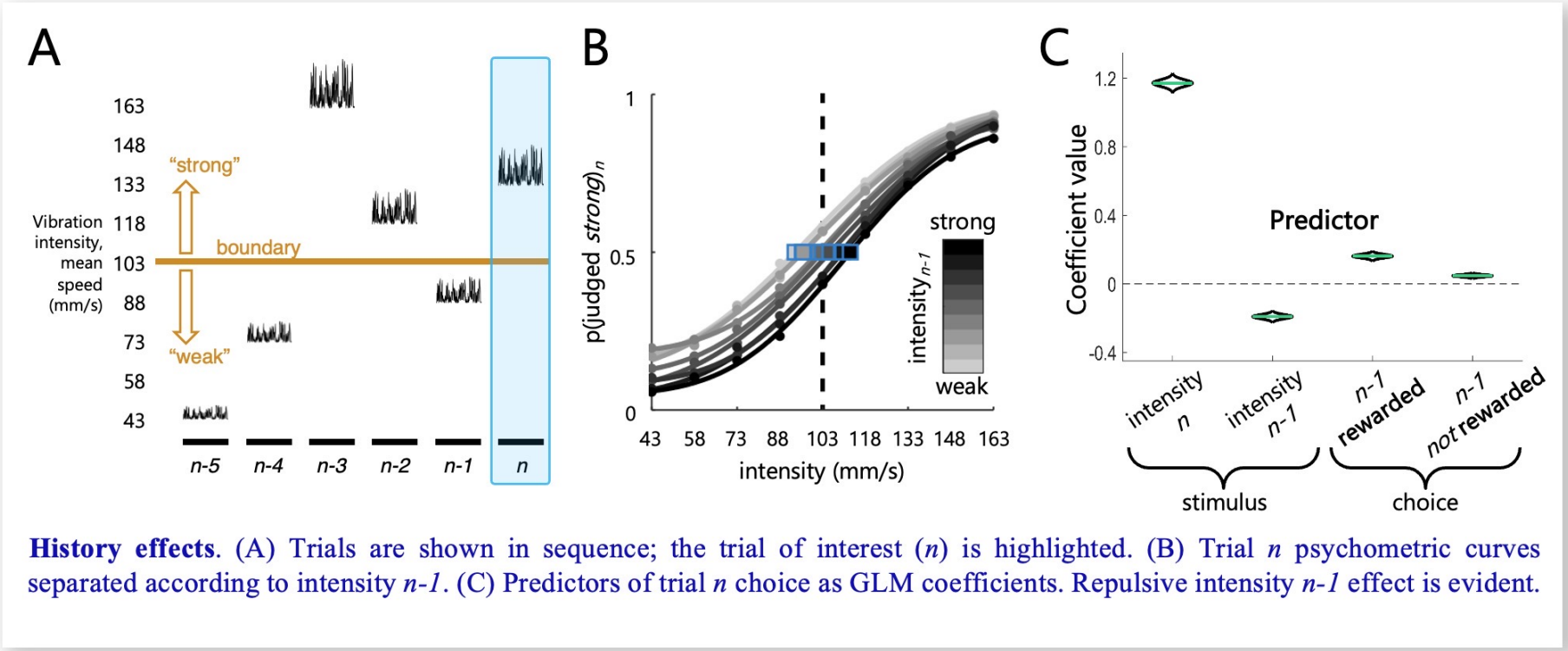

AFRICA
Addis Ababa



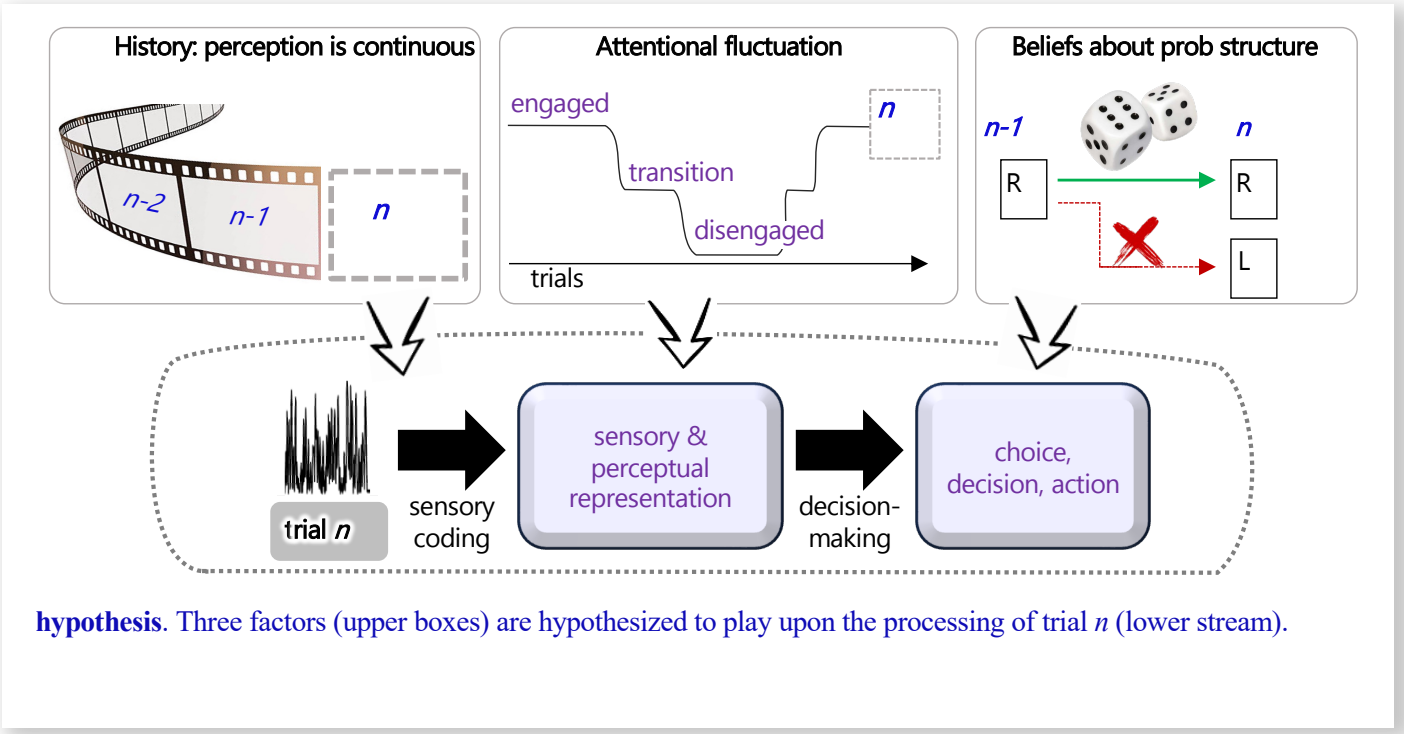
HYPOTHESIS

- 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”?



History effects. (A) Trials are shown in sequence; the trial of interest (*n*) is highlighted. (B) Trial *n* psychometric curves separated according to intensity *n-1*. (C) Predictors of trial *n* choice as GLM coefficients. Repulsive intensity *n-1* effect is evident.



hypothesis. Three factors (upper boxes) are hypothesized to play upon the processing of trial *n* (lower stream).

HYPOTHESIS

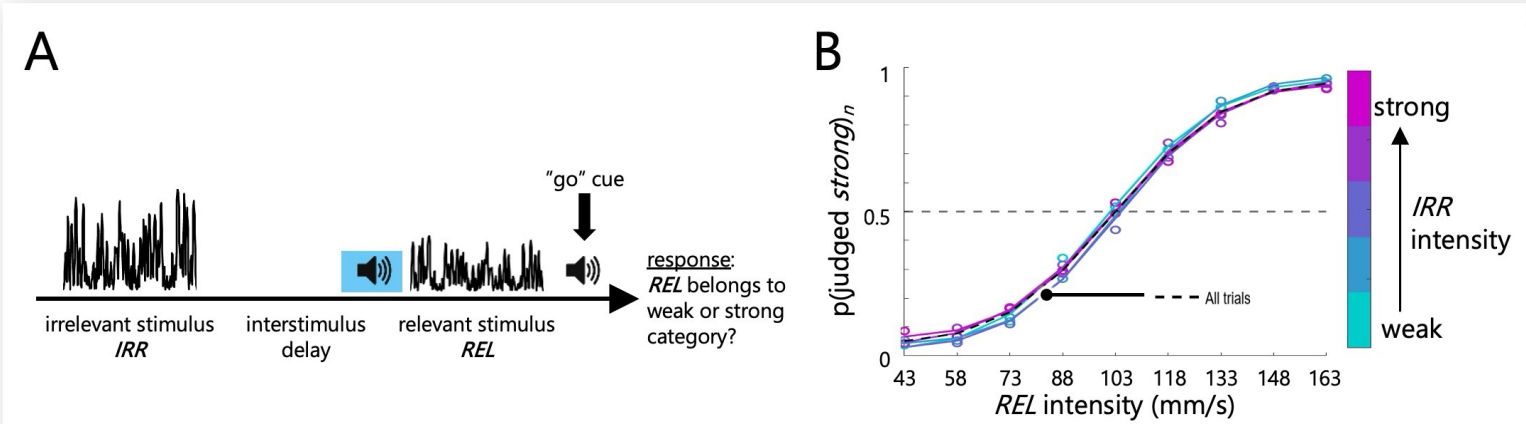
Trial *n* sensory information (lower stream) is transmitted to downstream regions where a transformation to decision and action is executed. Three separable factors (upper stream) interact with this processing stream and, together, account for most of the trial-to-trial choice variability enacted on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

What do we mean by “attentional fluctuation”?

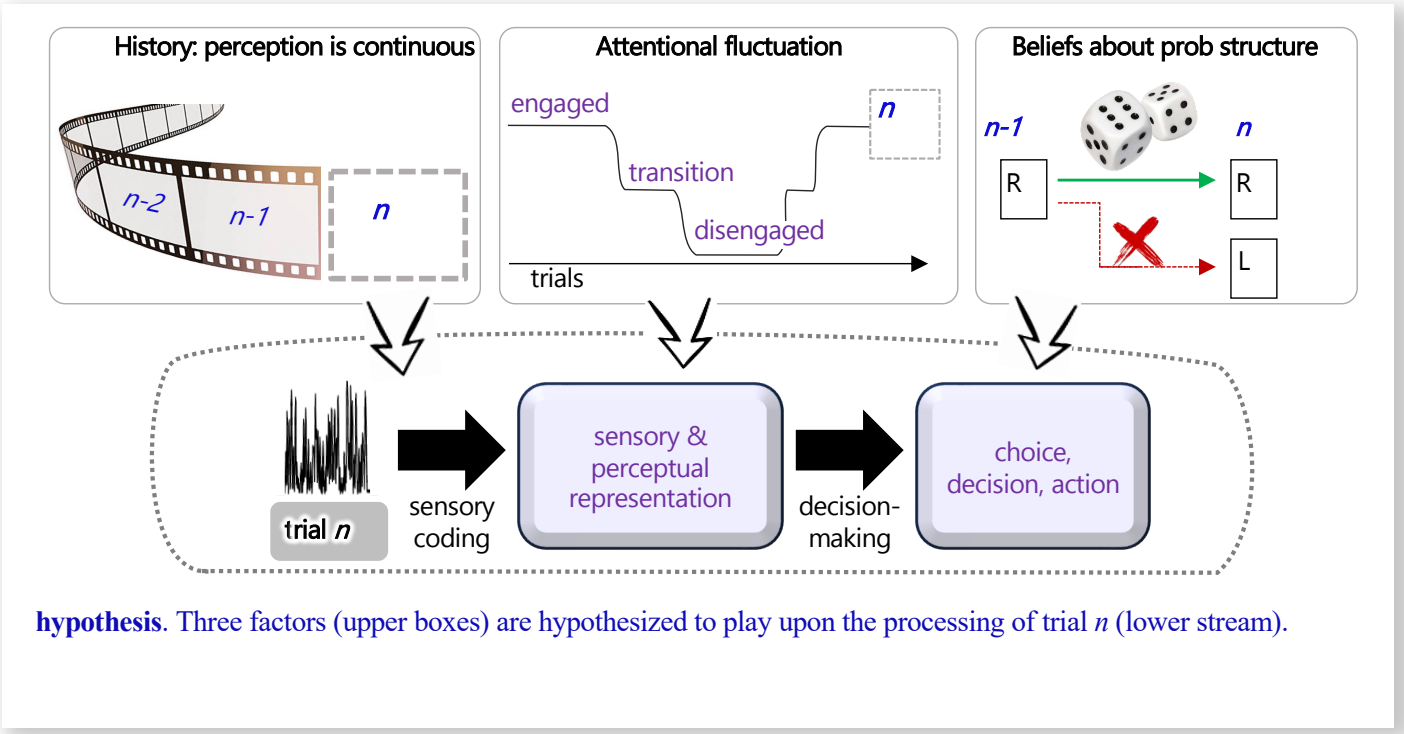
What do we mean by “attentional fluctuation”?

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



Attention under experimental control. (A) The task-relevant stim (*REL*) is proceeded 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*.

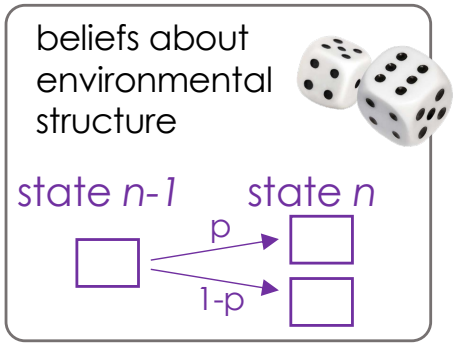


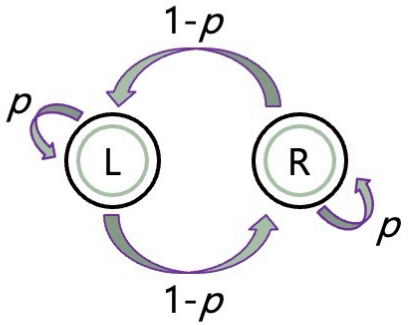
hypothesis. Three factors (upper boxes) are hypothesized to play upon the processing of trial *n* (lower stream).

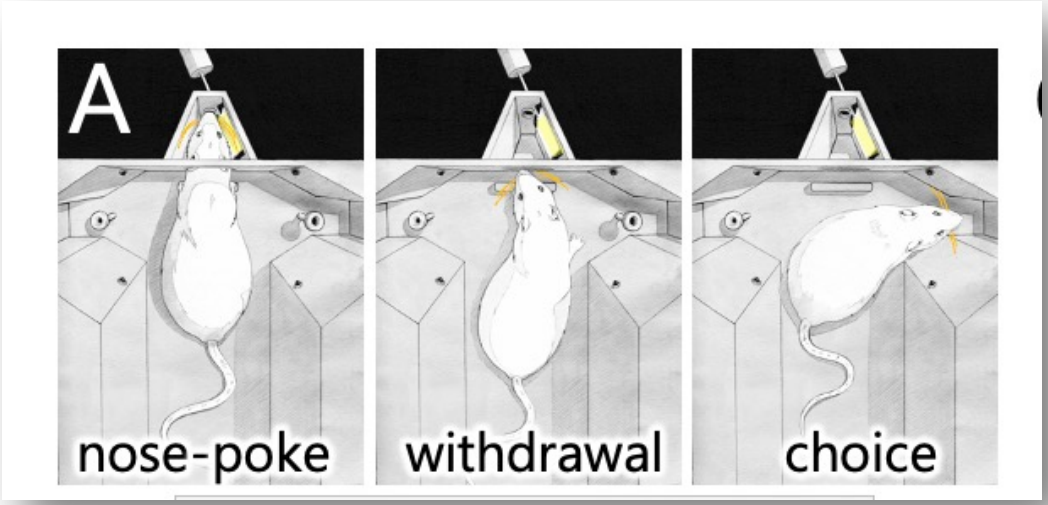
HYPOTHESIS

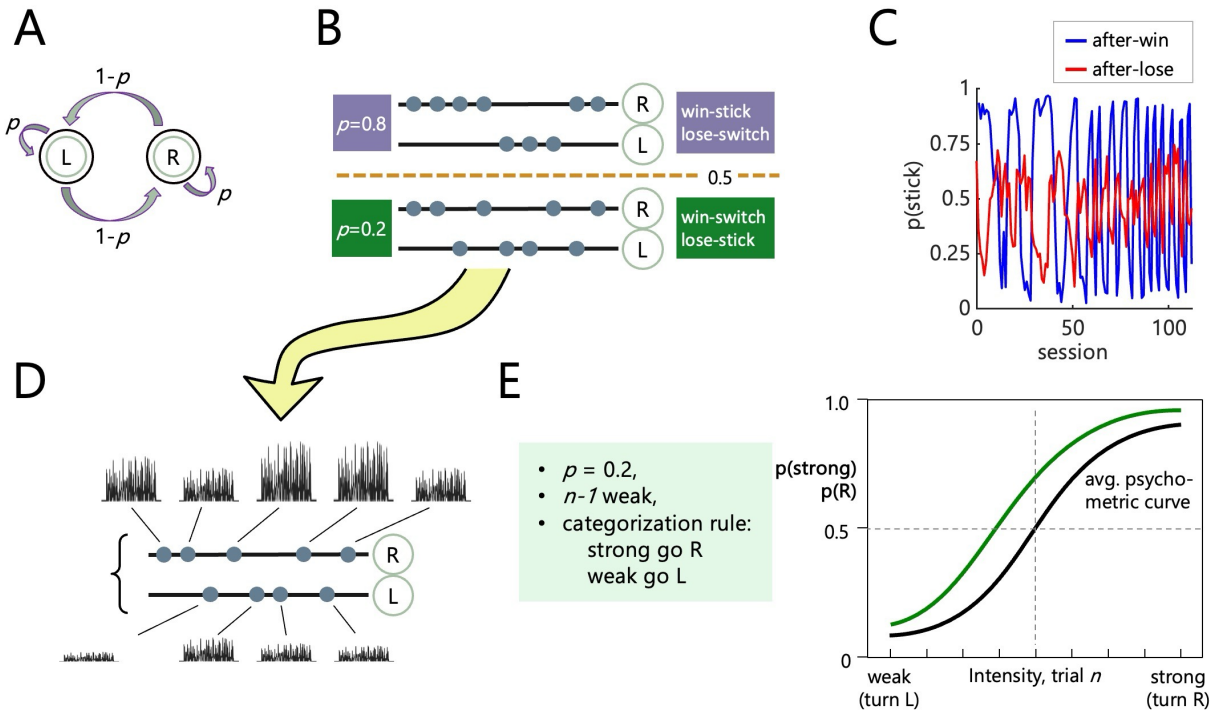
Trial *n* sensory information (lower stream) is transmitted to downstream regions where a transformation to decision and action is executed. Three separable factors (upper stream) interact with this processing stream and, together, account for most of the trial-to-trial choice variability enacted on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

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


beliefs about
environmental
structure
state n-1
state n
p
1-p

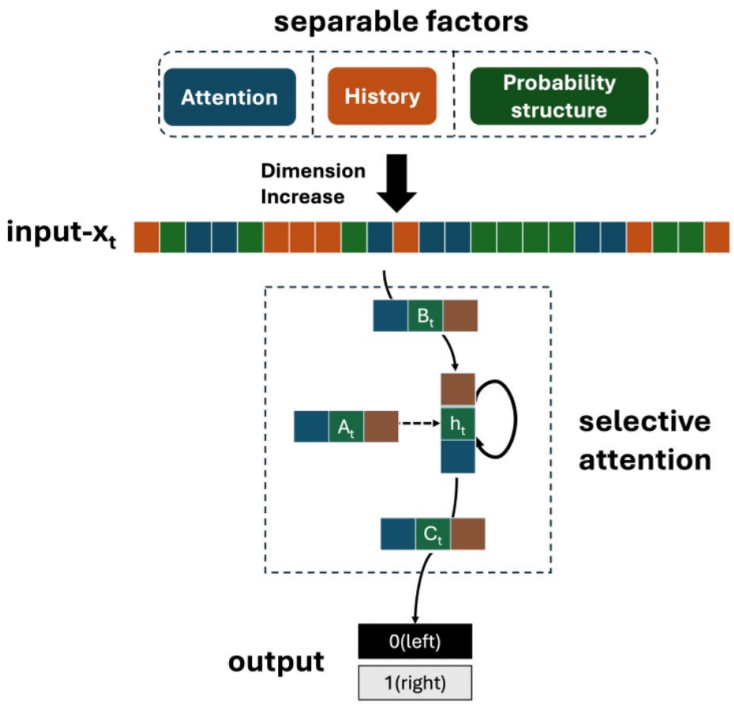

1-p
p
L
R
p
1-p


A
nose-poke
withdrawal
choice



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(stick) after-win and low p(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

***** 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

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

… beautiful research group