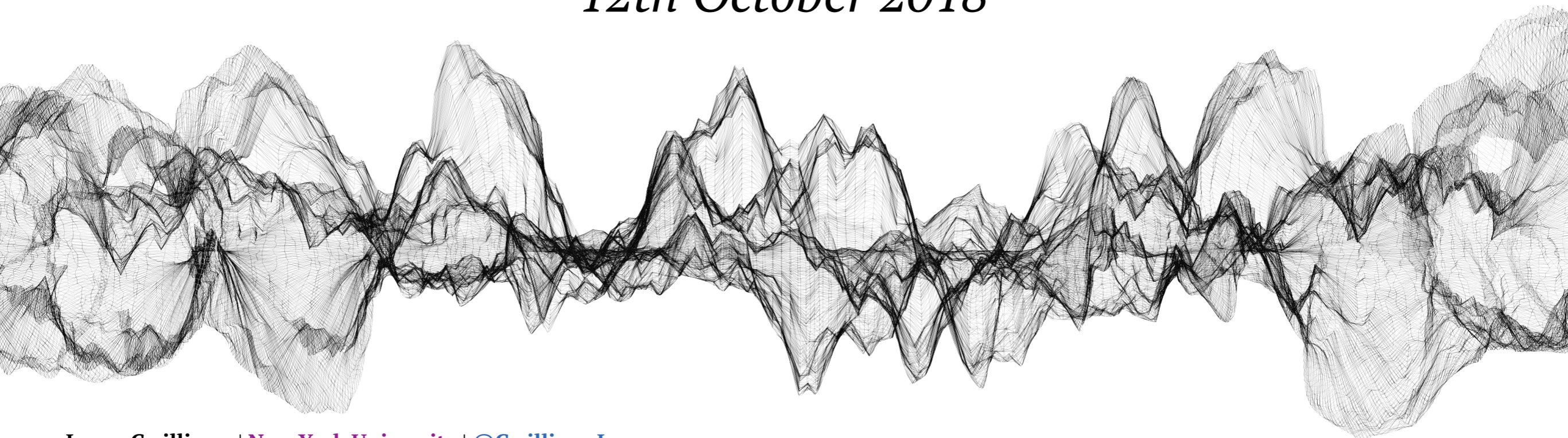# From brain responses to algorithms:
advances in parsing the computational architecture of perceptual decision making with MEG and machine learning
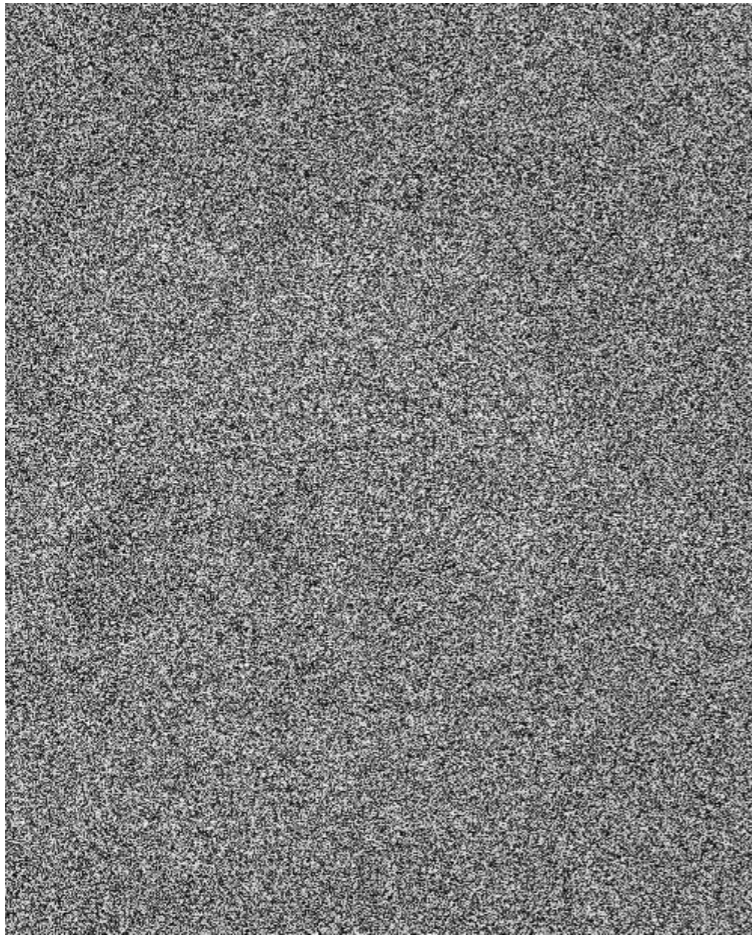
Laura Gwilliams & Jean-Rémi King
12th October 2018

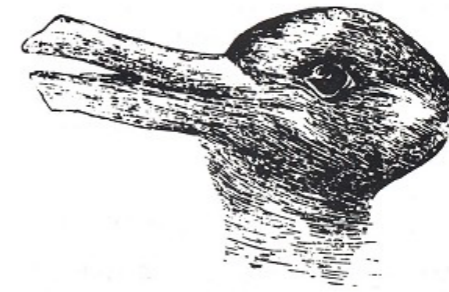**Laura Gwilliams** | New York University | @GwilliamsL
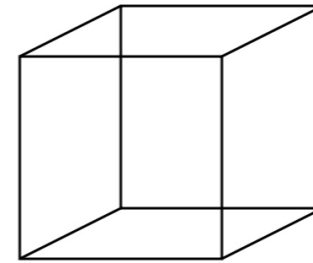
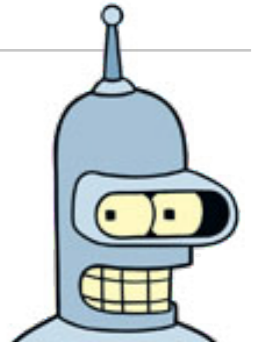# The world is an uncertain place
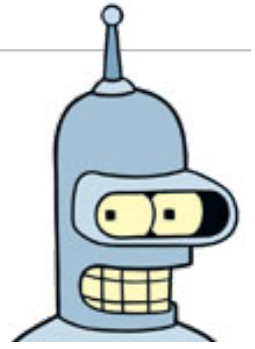
❖ Noise

❖ Ambiguity

AI can categorise, too

- ❖ Artificial intelligence has sought to solve a similar problem in visual processing

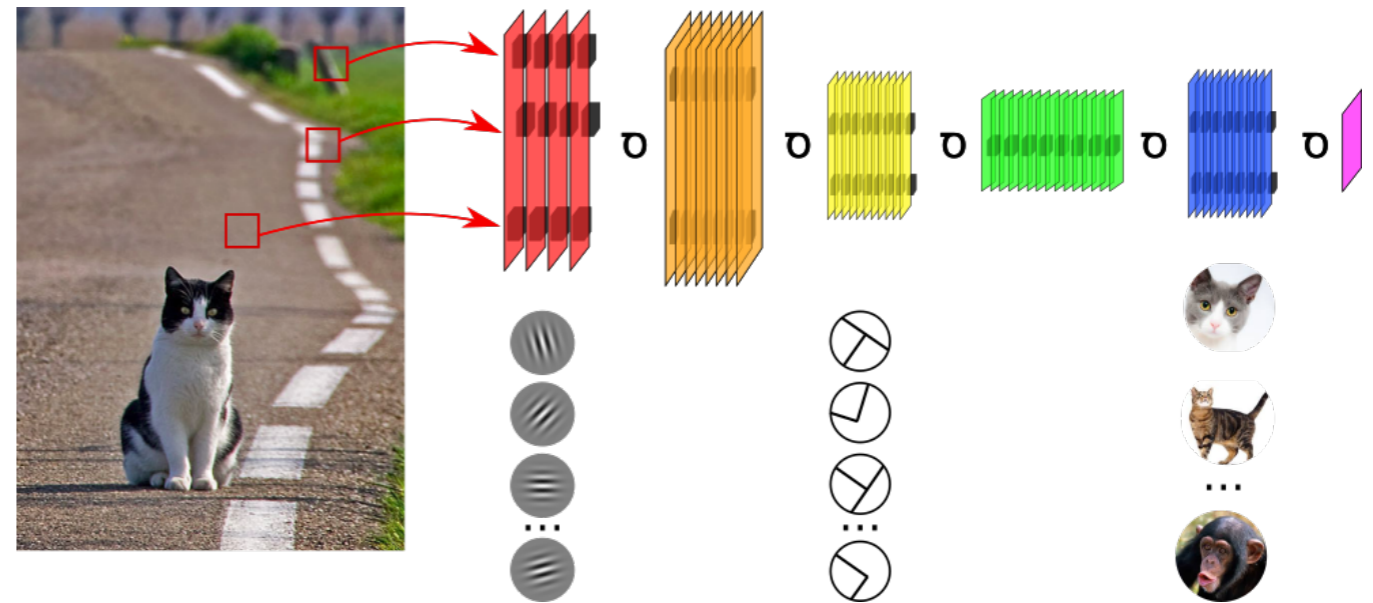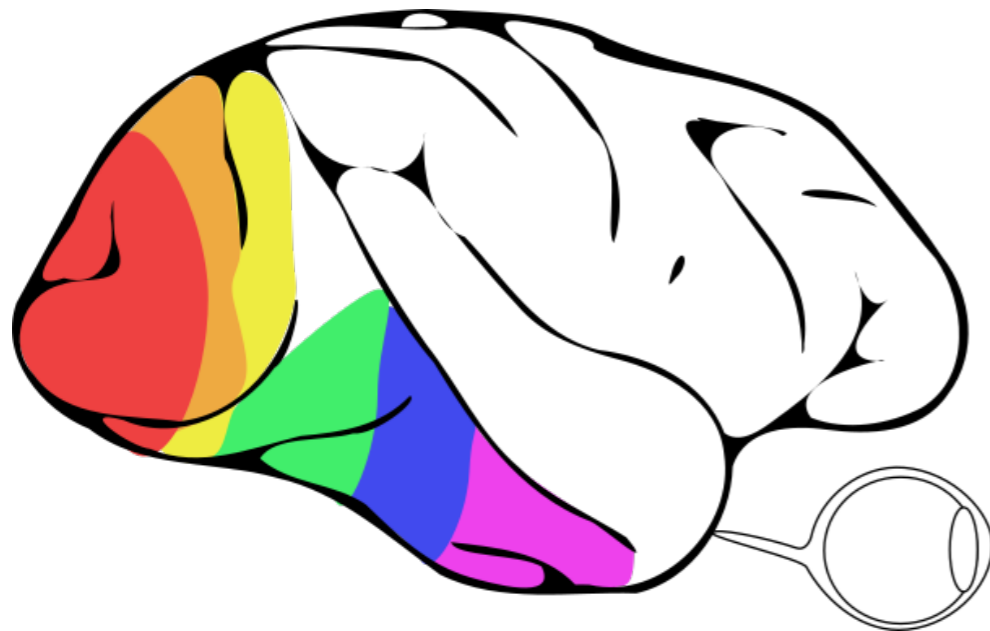- ❖ Deep neural networks (DNNs) can label images very accurately

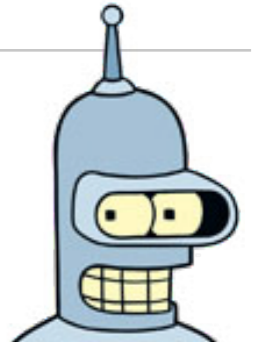**Laura Gwilliams** | New York University | @GwilliamsL

AI and neural convergence

❖ Correspondence has been found in terms of the *representations* employed by brains and DNNs

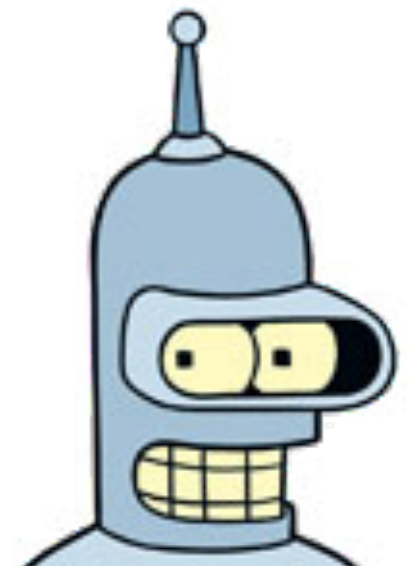Laura Gwilliams | New York University | @GwilliamsL
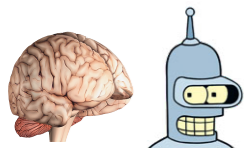
Yamins et al., 2014

AI and neural convergence

❖ Not so surprising, given that aspects of DNNs are modelled on vision neuroscience

❖ There is more to characterising a system than simply knowing the representations it uses:

  ❖ Architecture

  ❖ Computation

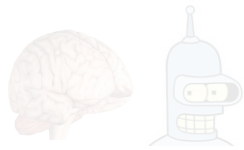Laura Gwilliams | New York University | @GwilliamsL

Research Question

What is the computational architecture of perceptual decision making?

Laura Gwilliams | New York University | @GwilliamsL

Roadmap

What is the order of operations performed on the sensory input?
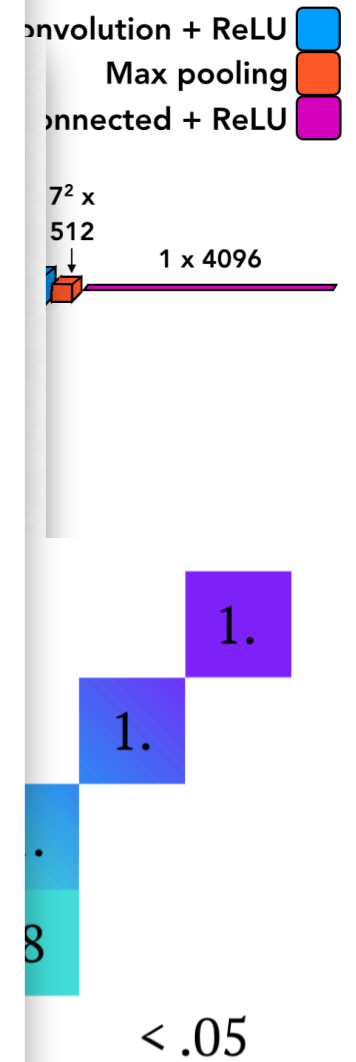
What are the underlying computations at the decision stage?

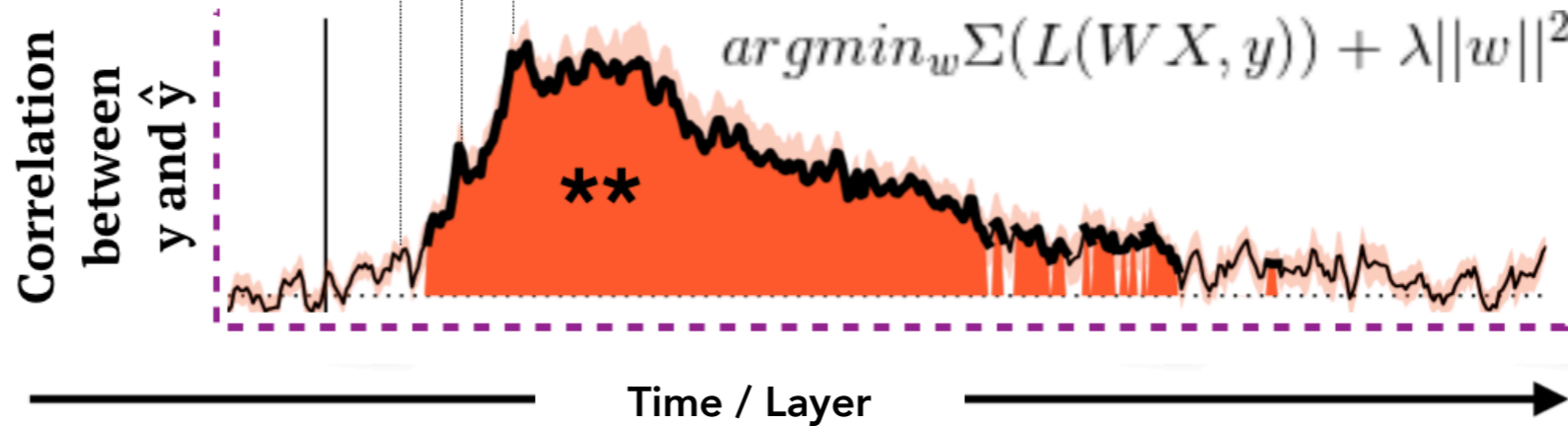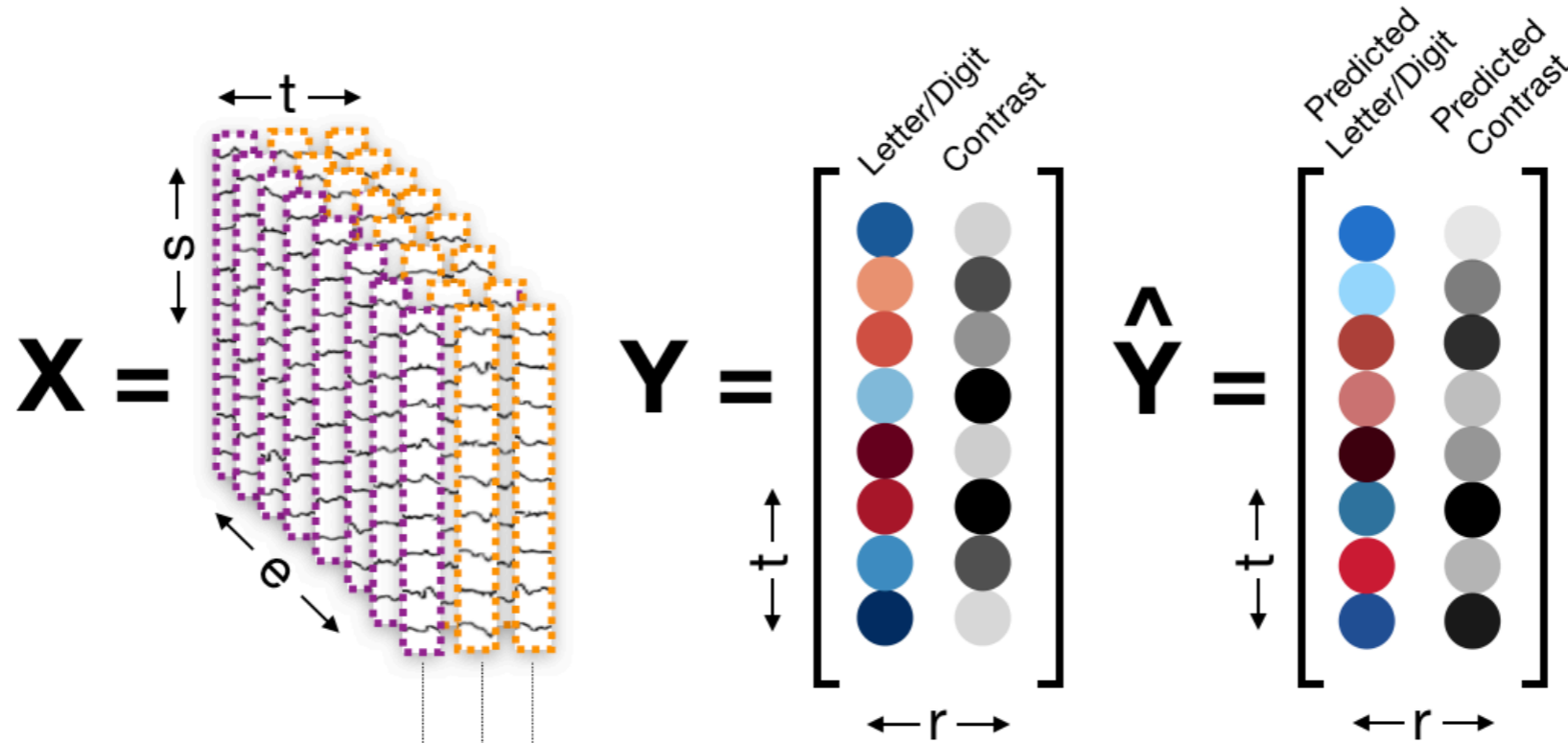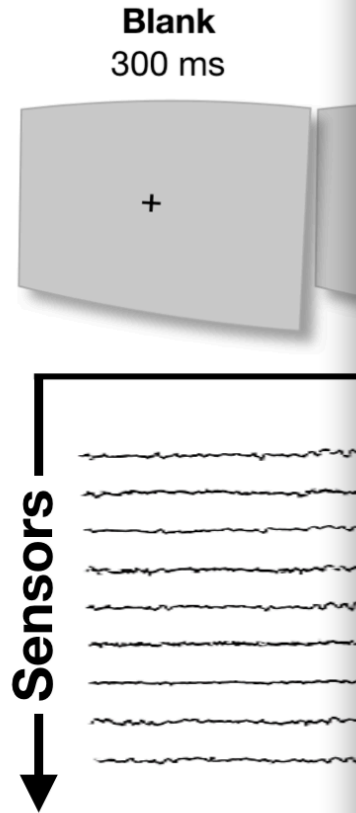How are the stages linked to one another?

Parallel Analysis

$X =$ $Y =$ $\hat{Y} =$

$$argmin_w \Sigma(L(WX, y)) + \lambda||w||^2$$

Correlation between y and $\hat{y}$

**

Time / Layer

position (left / right)

$< .05$

Laura Gwilliams | **New York University** | **@GwilliamsL**

Roadmap

What is the order of operations performed on the sensory input?

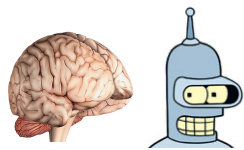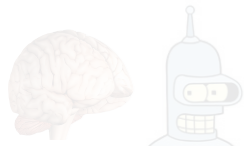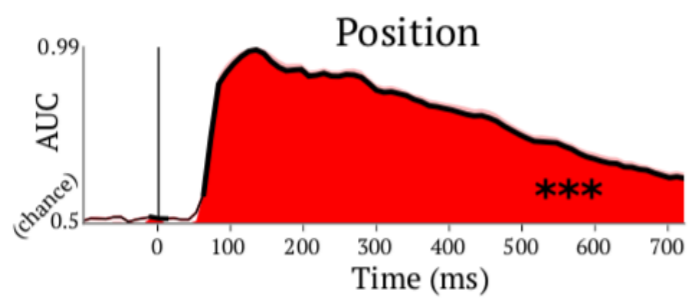What are the underlying computations at the decision stage?
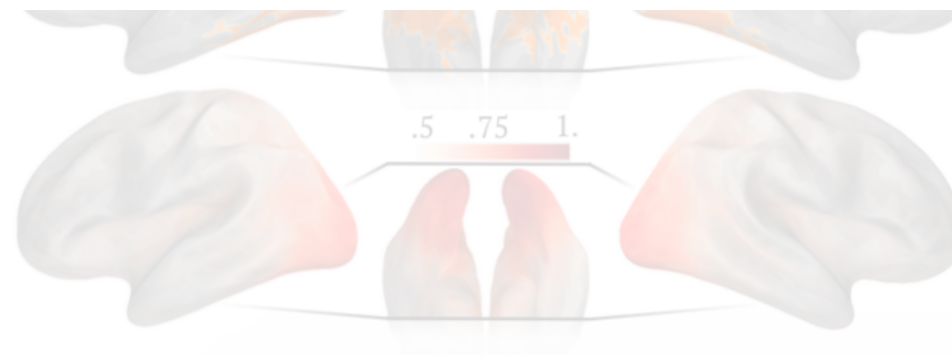
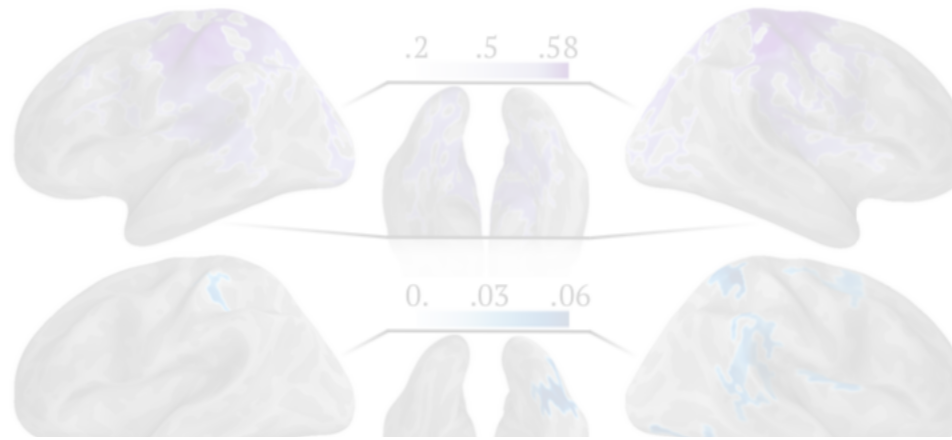How are the stages linked to one another?

MEG
Decoding Scores

Position

Laura C   nsl

MEG
Decoding Scores

Motor Side

Confidence

Position

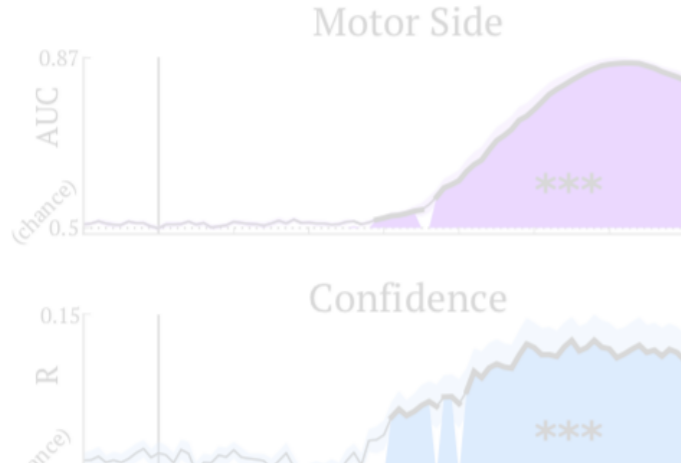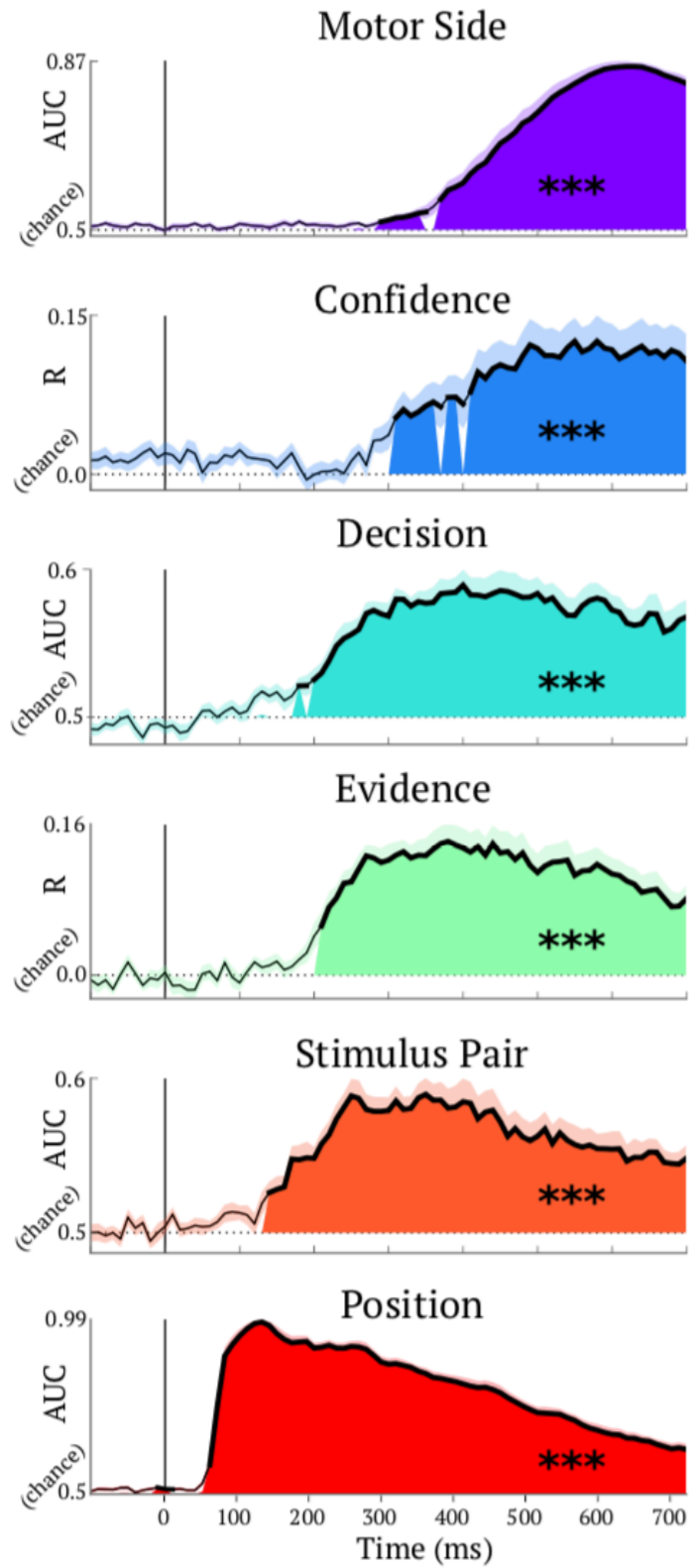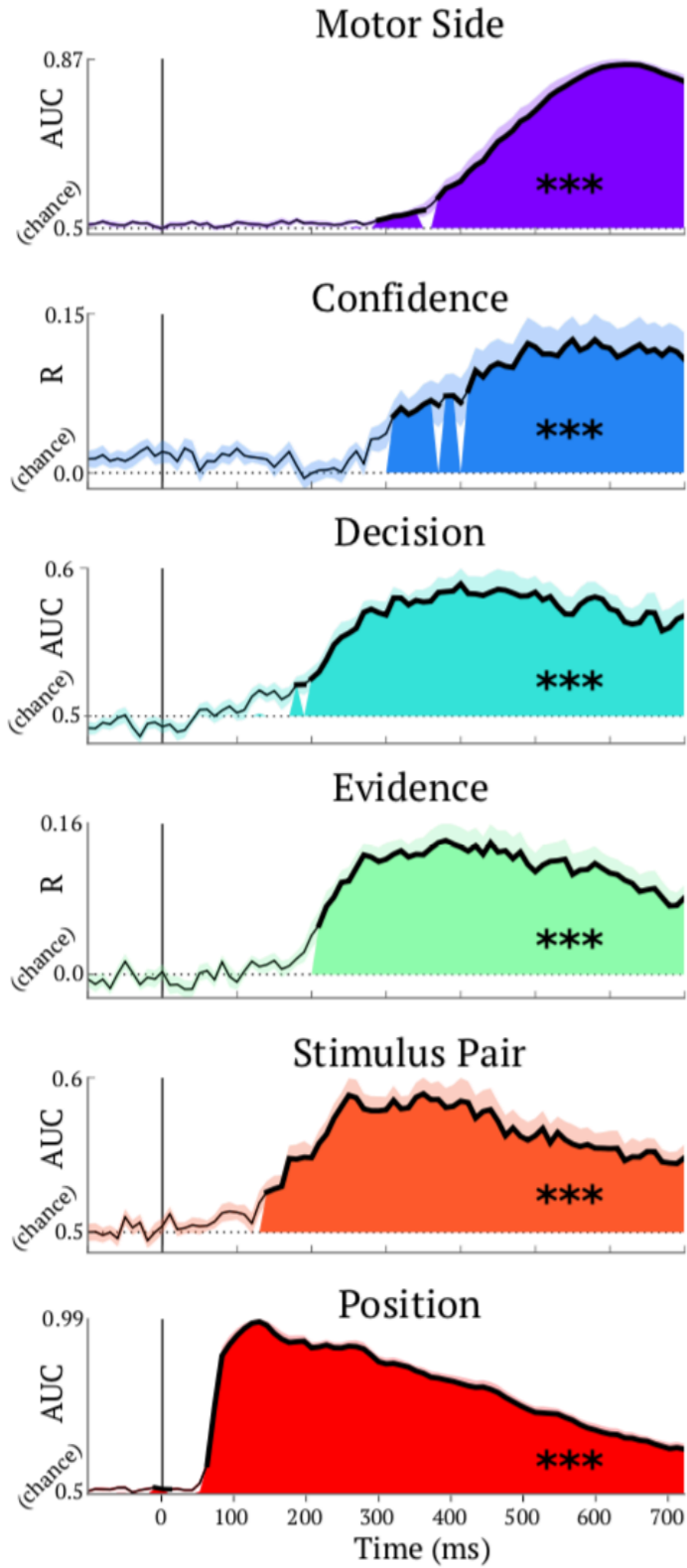Laura   nsL
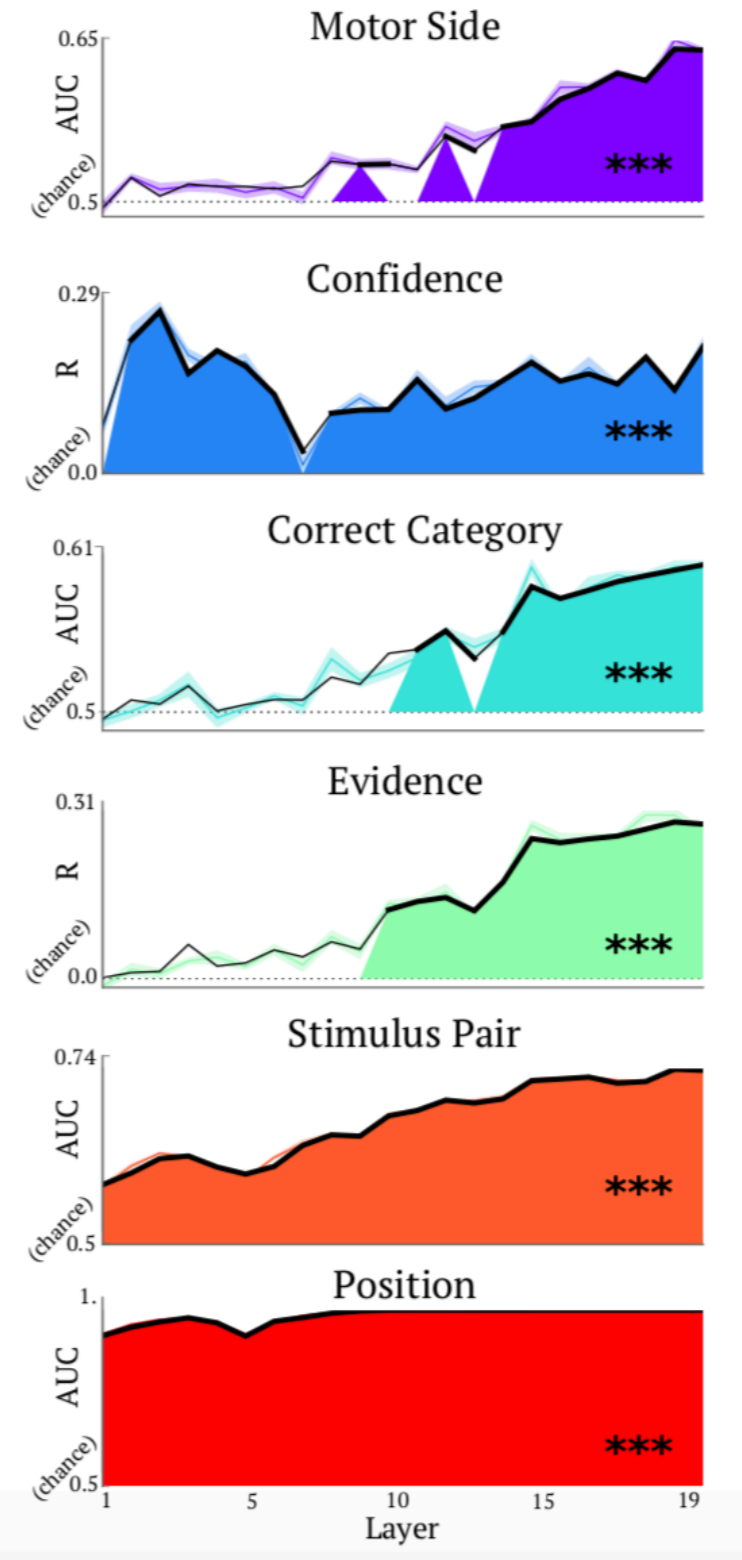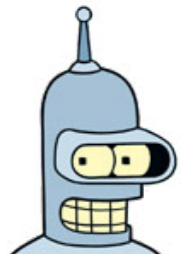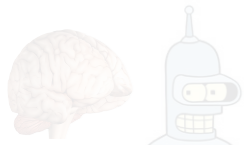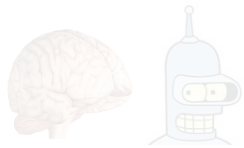
MEG Decoding Scores

MEG Decoding Scores

DNN Decoding Scores

Roadmap

What is the order of operations performed on the sensory input?

What are the underlying computations at the decision stage?

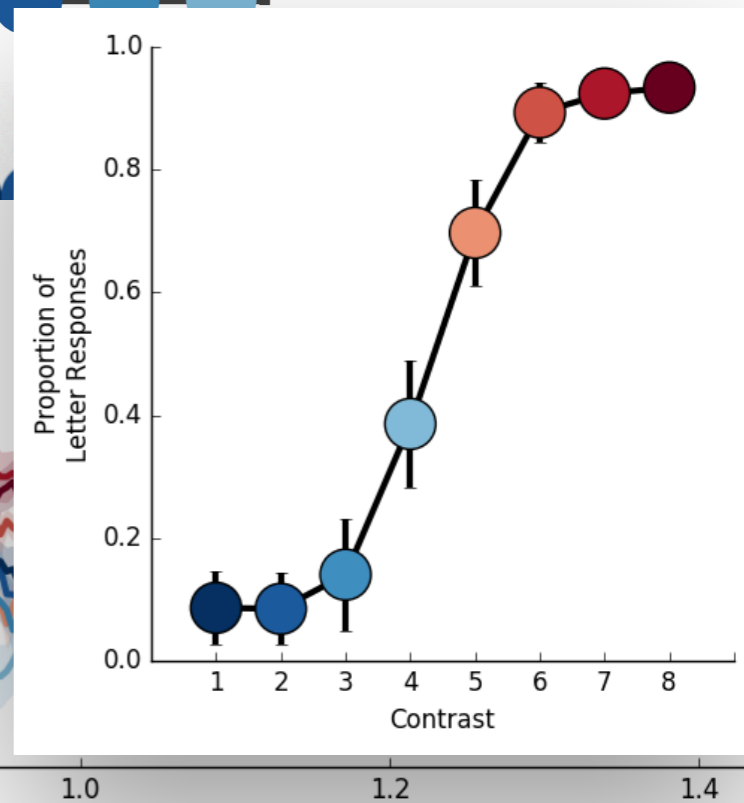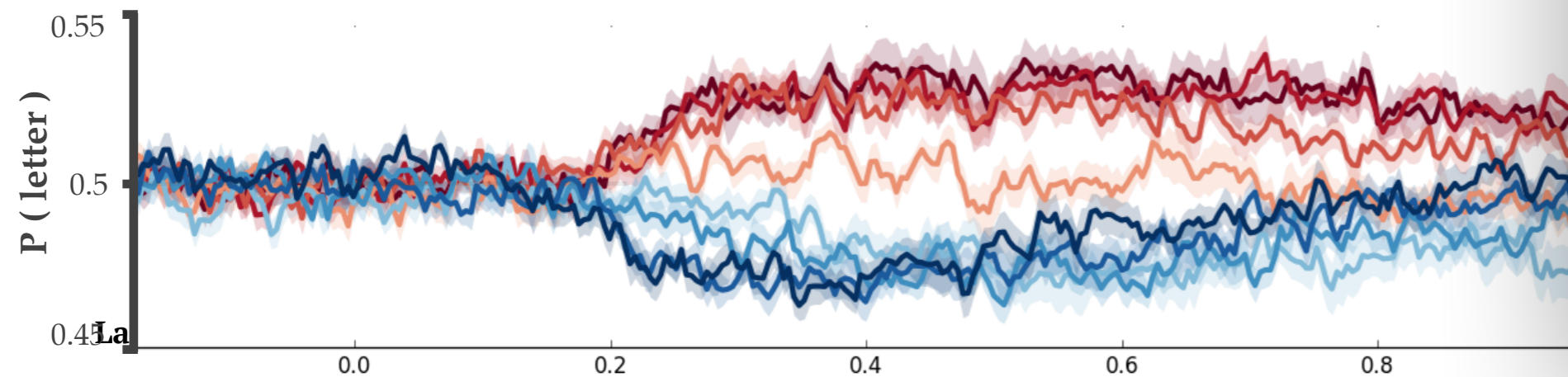How are the stages linked to one another?

What are the underlying computations?

Linear Evidence

Categorical Percept

What are the underlying computations?

Time: -0.0 s

What are the underlying computations?

Roadmap

What is the order of operations performed on the sensory input?

What are the underlying computations at the decision stage?

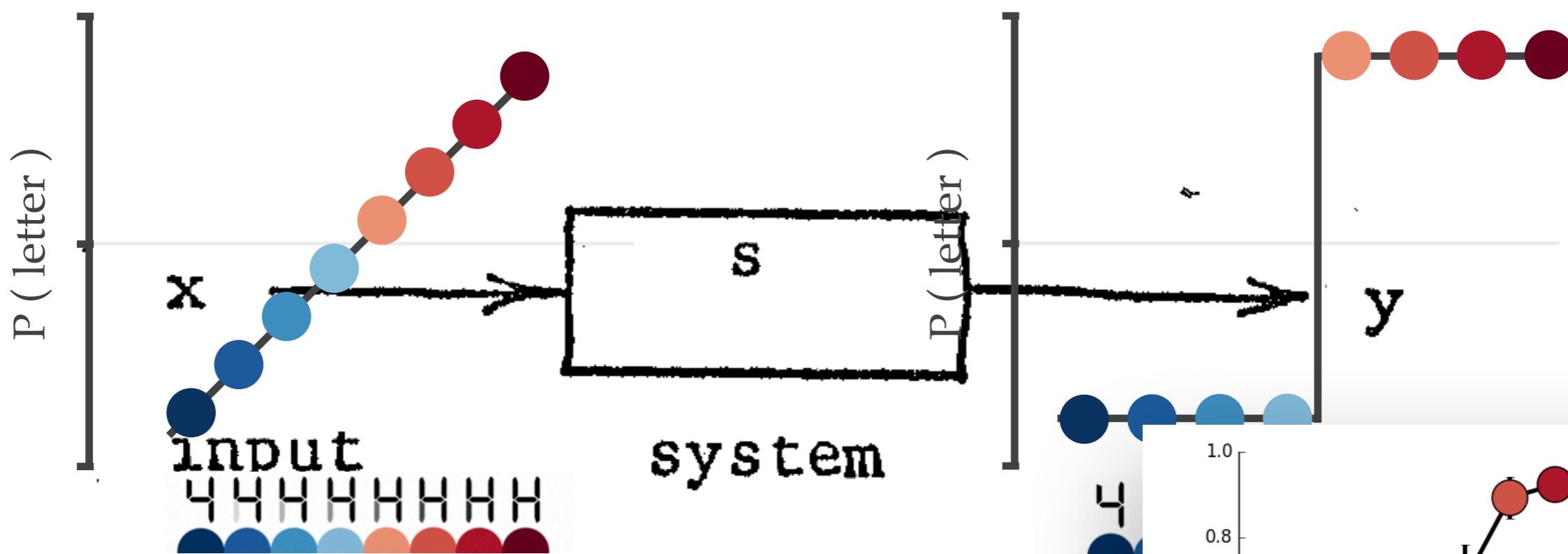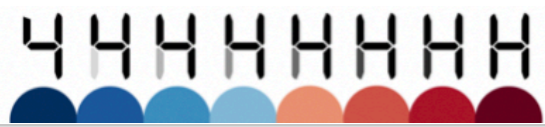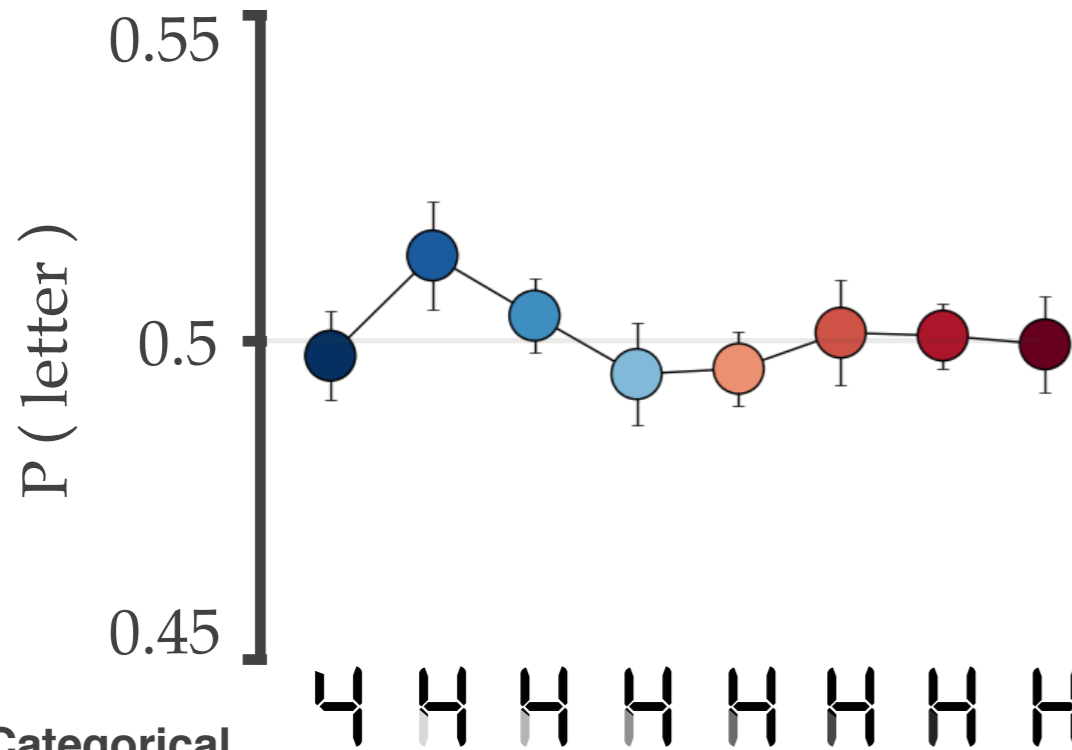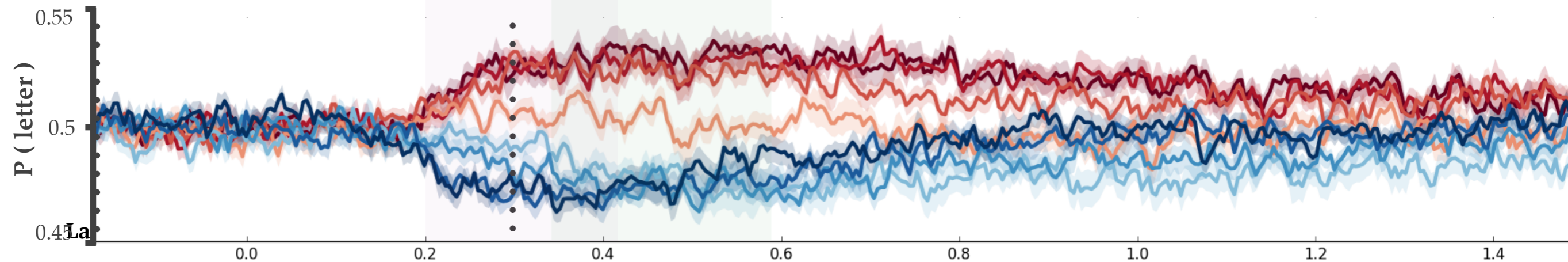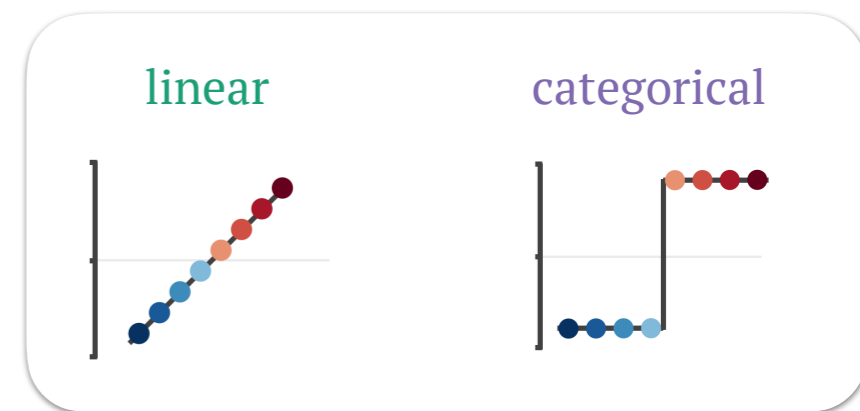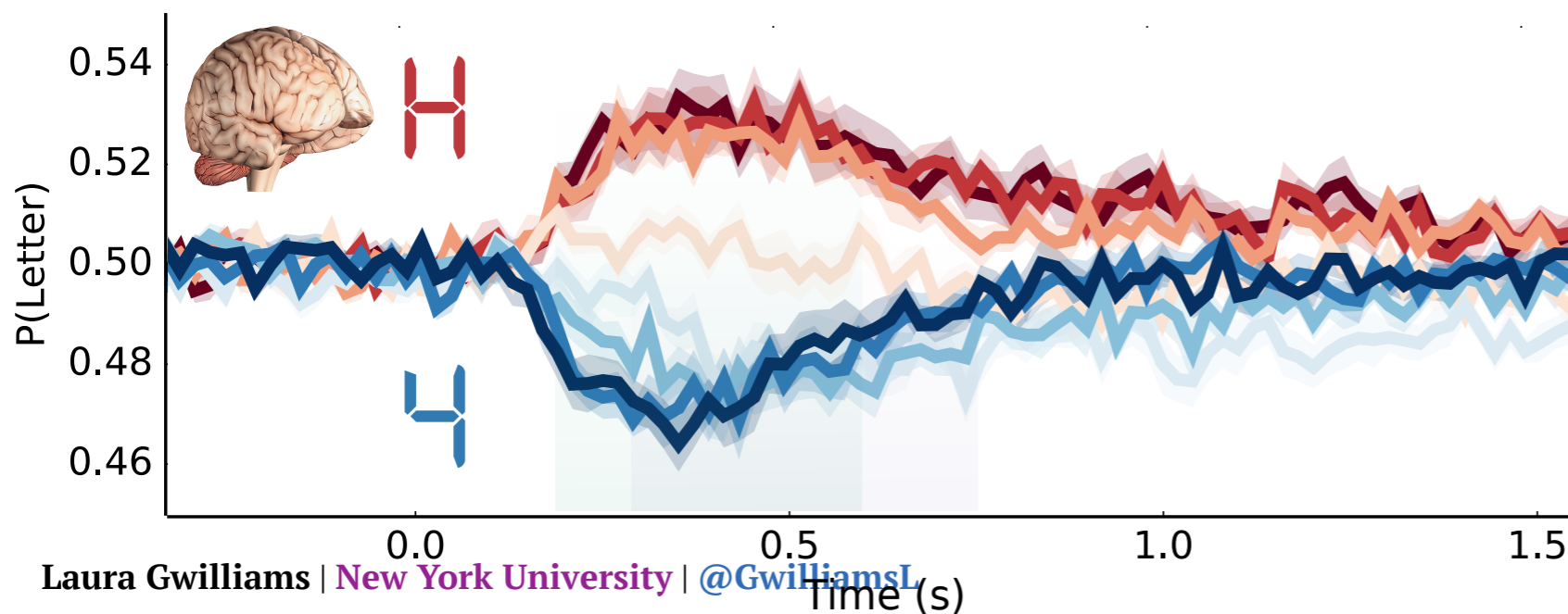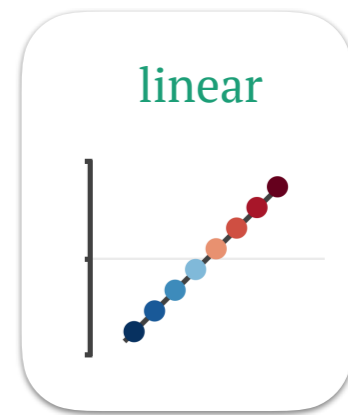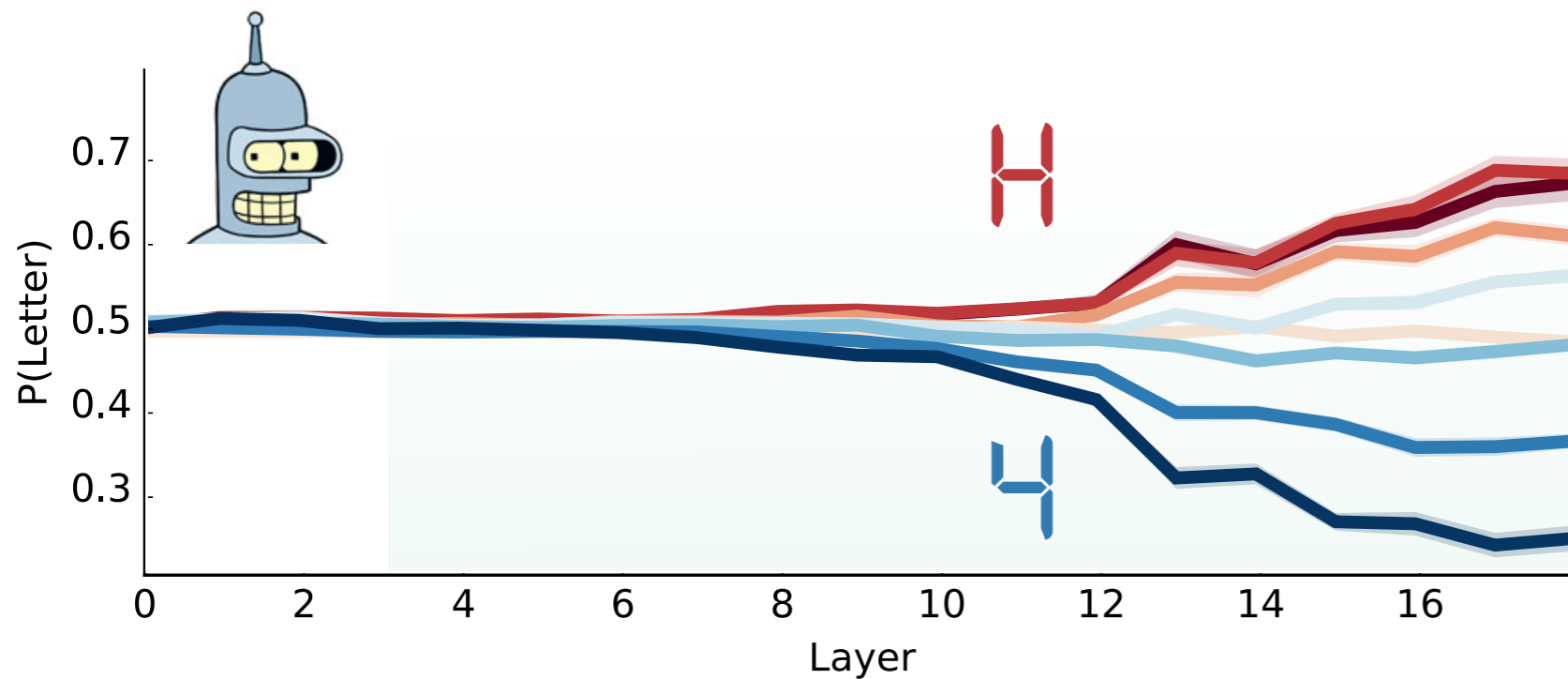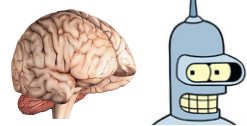How are the stages linked to one another?

Laura Gwilliams | New York University | @GwilliamsL

Roadmap

What is the order of operations performed on the sensory input?

What are the underlying computations at the decision stage?

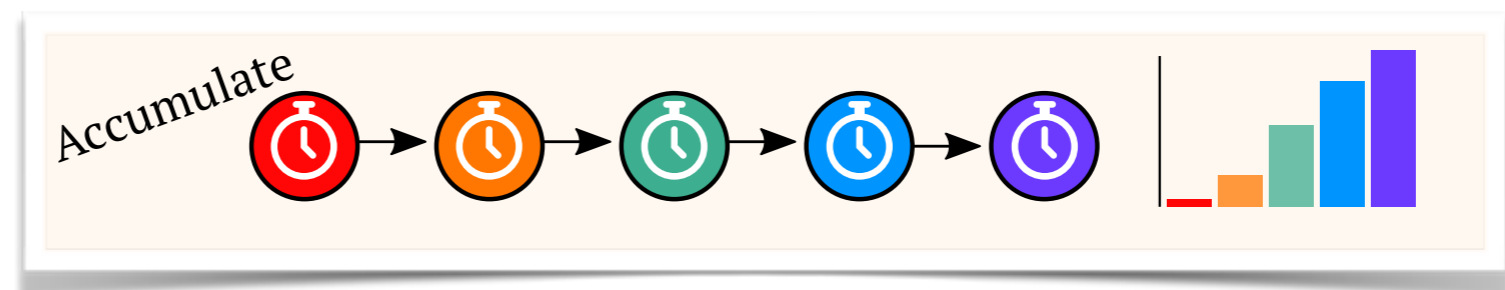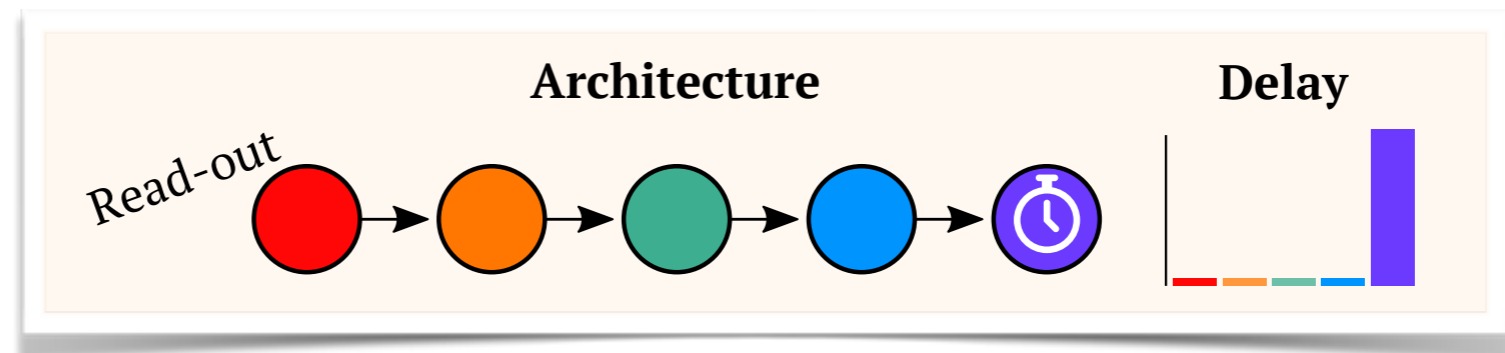How are the stages linked to one another?

Linking processing stages

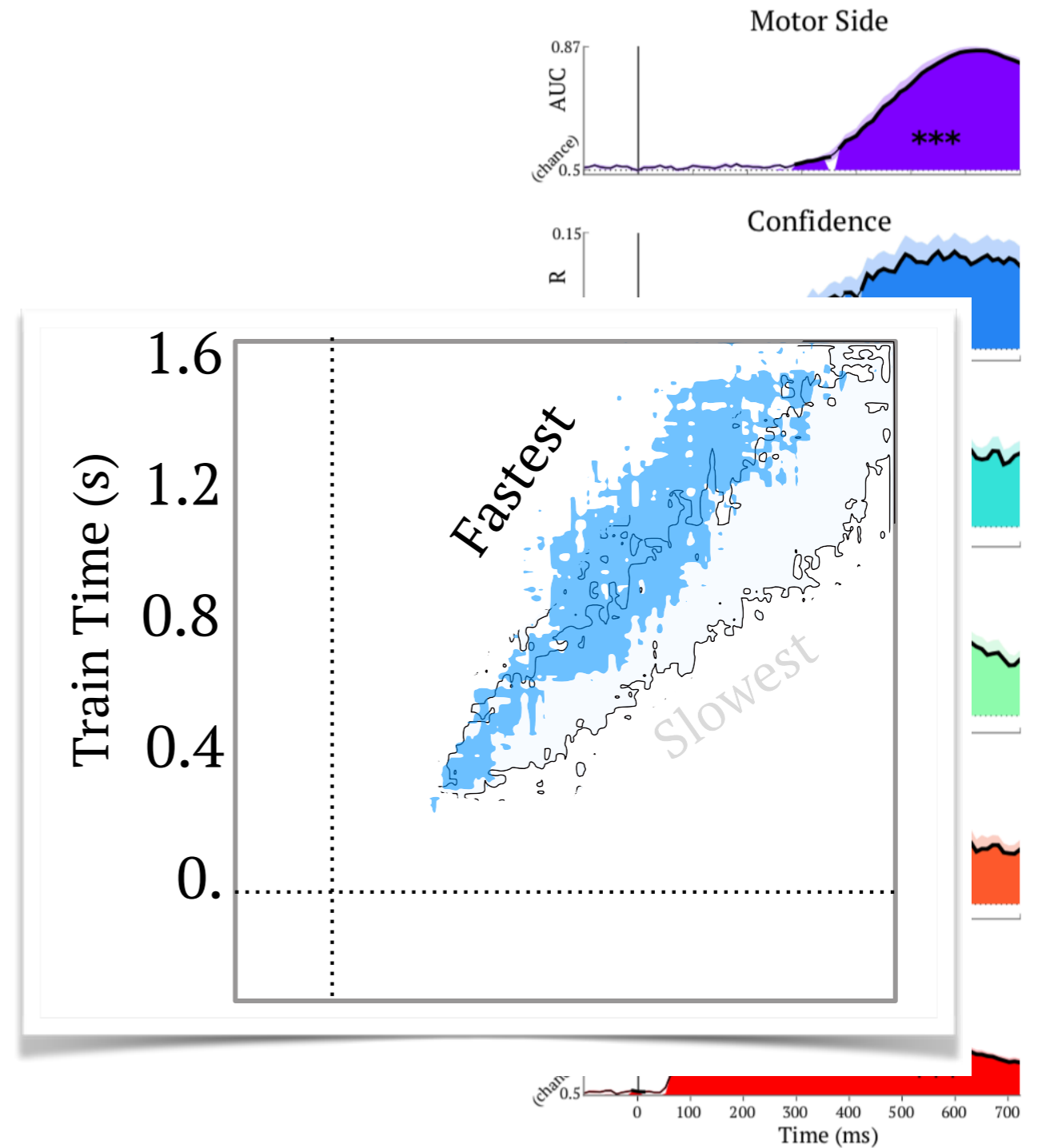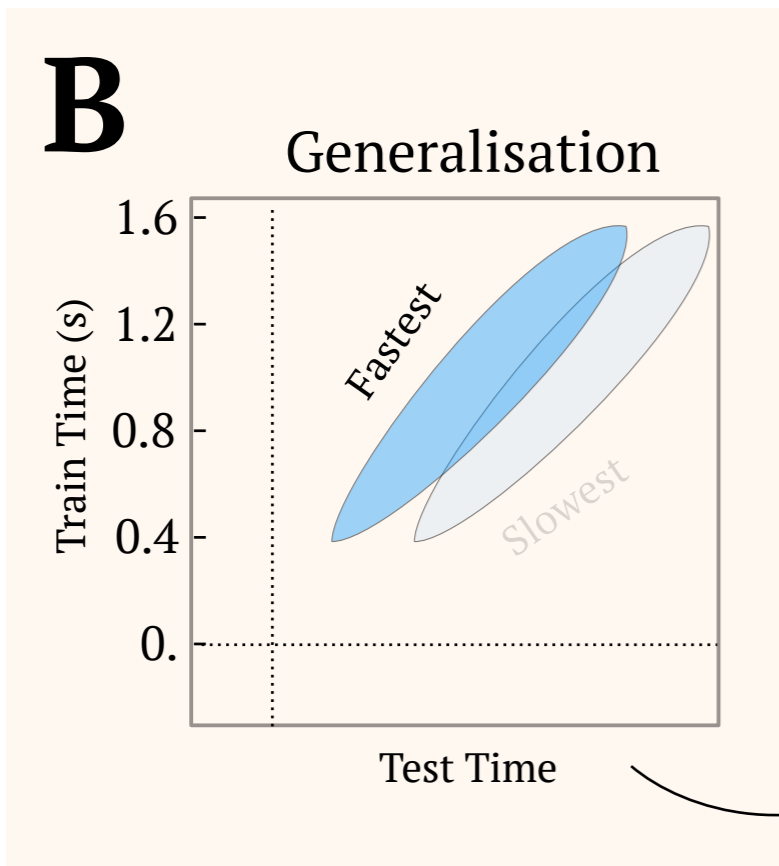❖ Human performance varies on a trial to trial basis

Laura Gwilliams | **New York University** | **@GwilliamsL**

Linking processing stages

❖ Where does this variation come from — during which processing stage?
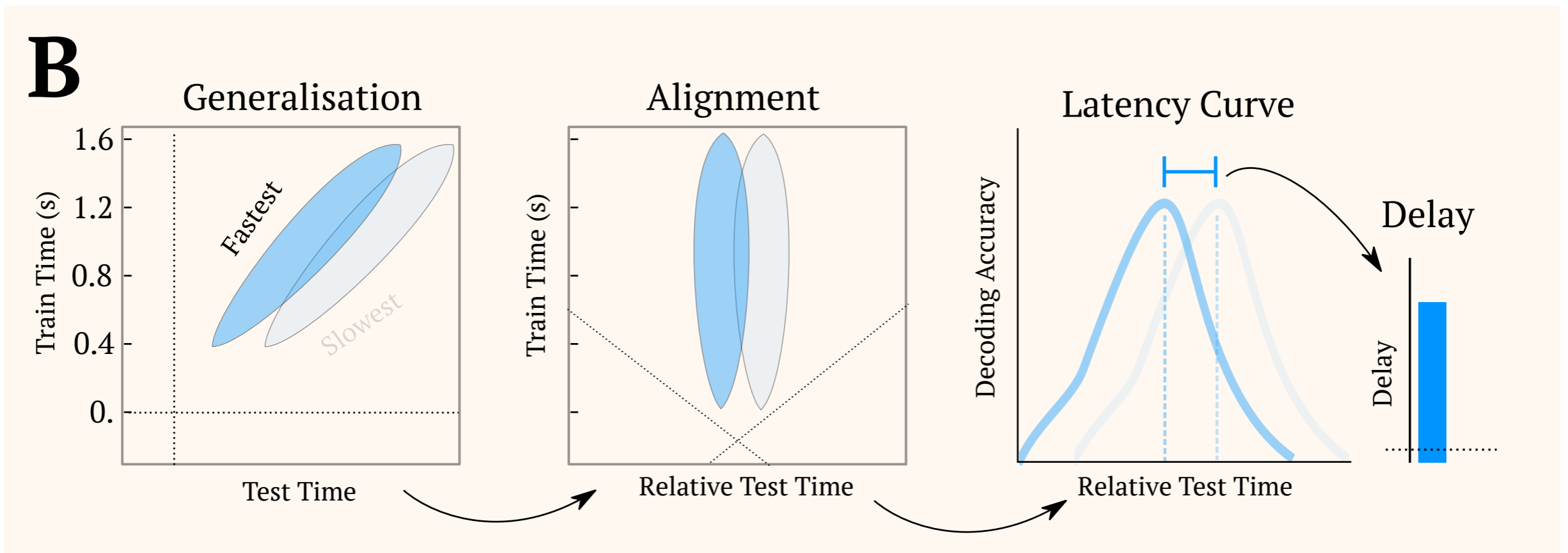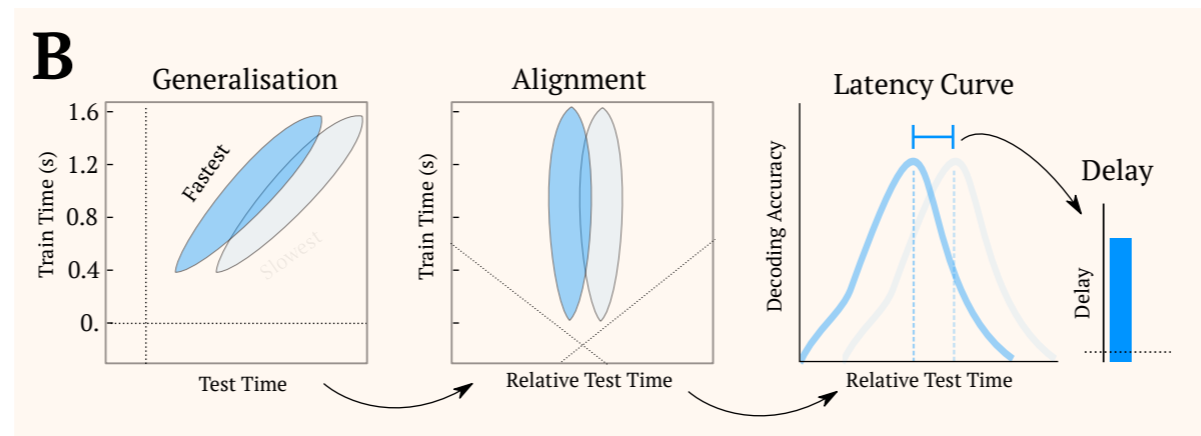
❖ Are processing delays propagated through the system?
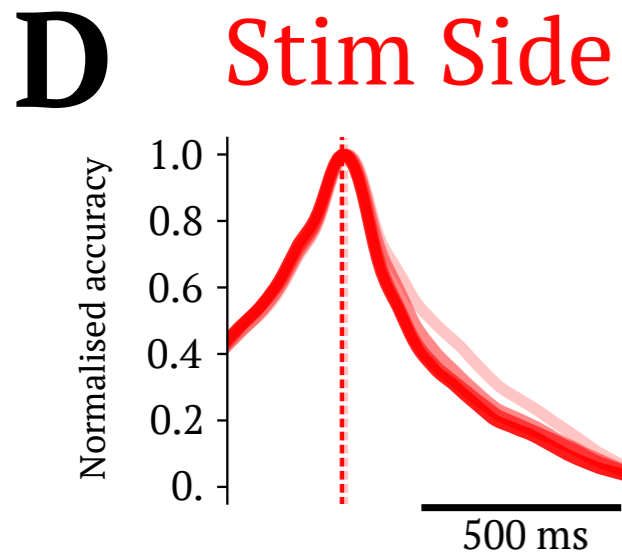
Linking processing stages

B Generalisation

Motor Side

Confidence

Linking processing stages

Laura Gwilliams | **New York University** | **@GwilliamsL**

B

Generalisation

Alignment

Latency Curve

Delay

processing delay emerges

processing delay accumulates

D Stim Side

500 ms

Laura Gwilliams | New York University | @GwilliamsL

Linking processing stages

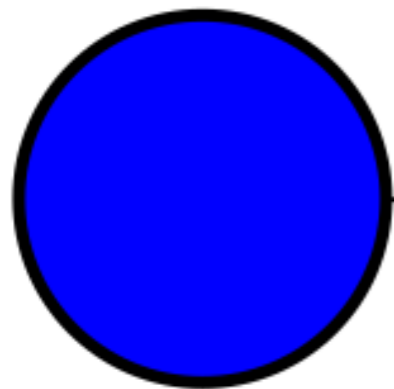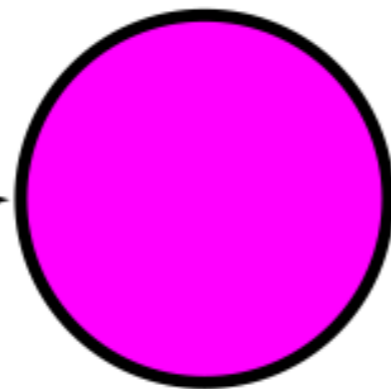**Laura Gwilliams** | **New York University** | **@GwilliamsL**

Discussion

❖ Behavioural delay can be linked to a processing delay from the decision stage onwards
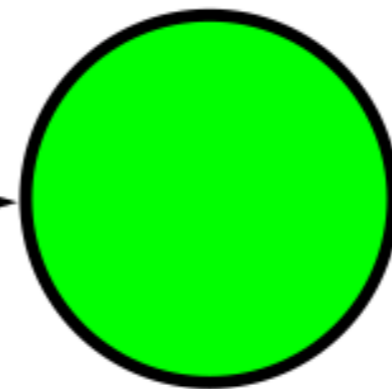
❖ Processing stages are sequentially linked

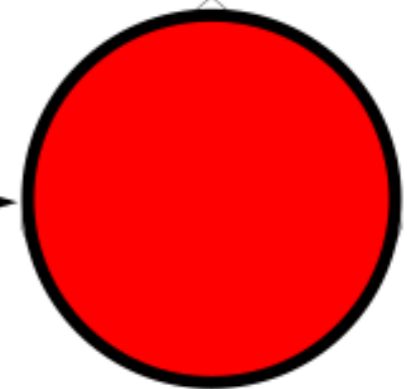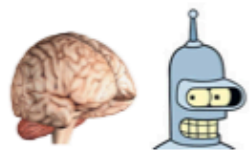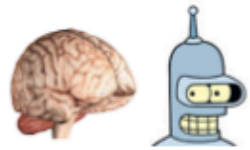Laura Gwilliams | New York University | @GwilliamsL

Conclusion

What is the order of operations performed on the sensory input?

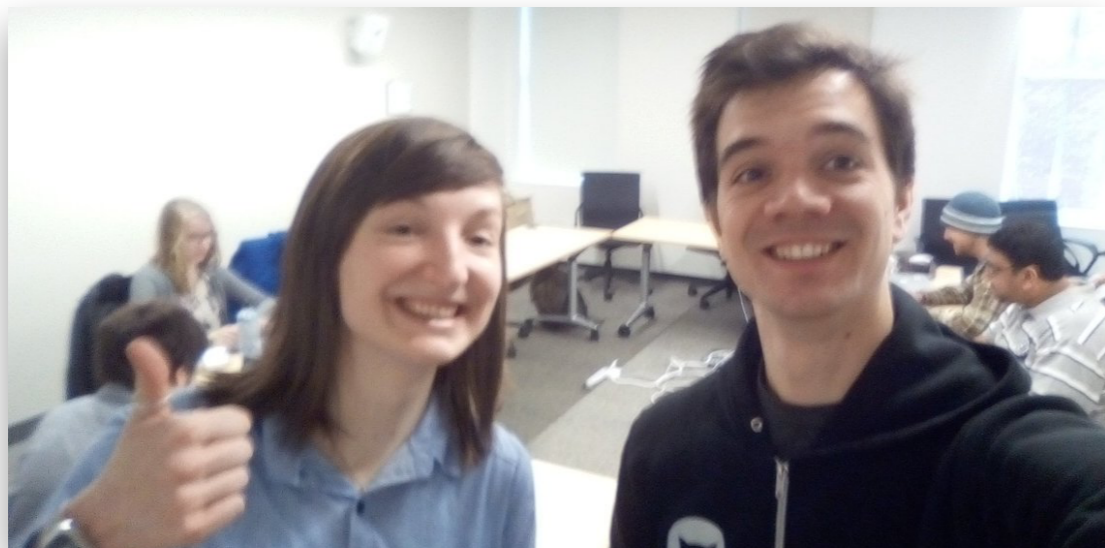What are the underlying computations at the decision stage?

How are the stages linked to one another?

Laura Gwilliams | New York University | @GwilliamsL

With big thanks to:

@GwilliamsL

- Collaborator **Jean-Rémi King**

- My supervisors, **Alec Marantz** and **David Poeppel**, and everyone in the **Neuroscience of Language Lab** and **Poeppel Lab**!

NYU

Laura Gwilliams | New York University | @GwilliamsL